PUBLISHER'S NOTICE.

The reader is requested to make suggestions as to desirable additions to the text of this book. Where can the author secure further cost data? What new subjects might advantageously be introduced in the next edition? A great service will be rendered not only to the author, but to the whole engineering profession by answering these questions. Our aim is to keep this book, as well as all other books that we publish, strictly up-to-date. Frequent revisions will be made. Therefore, if a reader would like to see any particular matter more fully treated, he will have our hearty co-operation.

HANDBOOK

OF

COST DATA

FOR

CONTRACTORS AND ENGINEERS

A REFERENCE BOOK GIVING METHODS OF CONSTRUCTION AND ACTUAL COSTS OF MATERIALS AND LABOR ON NUMEROUS ENGINEERING WORKS

BY

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PREFACE.

Four years ago I announced in my little book, "Economics of Road Construction," that I had in preparation a handbook of cost data for engineers and contractors. At that time this handbook had been under way for eight years, and it seemed nearly ready for publication; but other duties prevented a speedy finishing of the task. The delay, however, has been fortunate in that I have added very much to my knowledge of the general subject. In the meantime, two books have grown out of the original manuscript, namely, my books on earthwork and on rock excavation. The writing of these two books has better fitted me for the writing of this book, and has put me in touch with many engineers and contractors who have generously furnished additional cost data.

So far as I know, this is the first book on engineering cost data ever published. There are "price books" written fo[illegible] use builders, but they are essentially what their n[illegible] implies—books on prices of materials and contract p[illegible]s. This book differs from all such works, aside from th[illegible]act that it covers the whole field of civil engineering, [illegible] that it is a book in which *costs* are analyzed and discussed. A contract *price* is one thing, a contract *cost* is an entirely different thing, in spite of the common confusion of these terms. In order fully to understand any analysis of unit costs it is necessary to have a detailed description of the methods used in construction and operation. Hence, although itemized cost data occupy many scores of pages in this book, there are many more scores of pages devoted to descriptions of how the work was done, the organization of the forces, and the machines used. The records, in all cases, are actual records taken from every available source of published information, from personal letters sent by engineers and contractors and from my own records.

It is often said that cost data are of no value to an inexperienced man. Generally the men who make such state-

ments are themselves possessed of few records of cost, or use this argument as an excuse for not making public such records as they do possess. The very secretiveness of men having cost data which they refuse to make public, nullifies their statement that such data can be of no use to others.

We also hear it argued that conditions vary so widely that grave errors occur when an attempt is made to apply published cost data. Those who have not been trained to study the conditions affecting costs are likely to make serious blunders in any case; but, if this book is in even a slight degree what it aims to be, it will be of greatest benefit to just such men; for it will indicate to them how to analyze costs and how to study methods of performing work economically.

Many of the erroneous ideas about the value of cost recording arise from a confusion of the term cost with the term price. This is not a handbook of prices, although many prices are given. I could have filled ten volumes with prices, and with summaries of costs written by engineers who have failed to state rates of wages and conditions under which the work was performed. But, a short time after publication, all such matter is hardly worth the ink that it is printed with, since wages and prices are subject to constant change.

The attention of contractors is called to the first part of the book in which systems of cost keeping are described. I have outlined what I believe to be some of the best systems of cost keeping. Samples of other record cards and methods than my own are shown; for my purpose has been to elucidate principles, rather than to exploit pet theories as to business management and accounting.

HALBERT P. GILLETTE.

New York, Sept. 1, 1905.

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HANDBOOK OF COST DATA.

SECTION I.

COST KEEPING, PREPARING ESTIMATES, ORGANIZATION OF FORCES, ETC.

Objects of Cost Keeping.—There are two principal objects in keeping itemized records of cost: (1) To enable the contractor or engineer to determine what will be fair unit prices for similar work in the future; and (2) to enable the contractor to analyze his expenditures with a view to improving his foremanship, class of laborers, plant equipment, and the like. To an engineer this second object is often of little consequence, excepting in so far as it assists him in better attaining the first object; but to a contractor the second object is of vital importance. Up to the present time few contractors have awakened to the possibility of effecting great savings in cost by simply developing a system of daily itemized cost recording. The cost of maintaining such a system, slight though it is, has not appeared to be justified by the results, because the results have not been made public by those who have developed cost recording systems. In fact, to the majority of contractors it appears to have occurred that there is but one advantage in accurate cost keeping, namely, the ability to predict the value of future work with slightly greater accuracy. The truth is, however, that this advantage is slight, indeed, compared with the discovery of laziness that results from keeping an itemized daily record of costs. I am speaking not only from my own experience, but from the experience of several of the most successful construction companies in America, whose managers have furnished me with many striking examples of reductions in cost effected by a study of the daily records of work done.

As incidental consequences of proper cost keeping there are certain other advantages, among which are the following: (1) The wits of the managers, foremen and skilled workers are sharpened; because each man feels that he is under a strict watch; and that there is a chance for merit to

become known, and, being known, to receive its reward. (2) Fewer foremen are required, and one good foreman can direct the work of a far greater number of men. (3) "Padded payrolls" are practically done away with, and thefts of tools, food and materials reduced to a minimum. (4) Machines are kept in better order and less subject to abuse, because a falling off in output of any machine due to such abuse is quickly discovered. (5) When a contractor is known to have a good system of daily recording his work, engineers and architects are more apt to favor giving him extra work, paying him actual cost plus a fixed sum, or plus a percentage for his supervision and the use of his plant.

These are some of the incidental advantages of keeping such a system of costs as I am about to outline, but the term "incidental advantages" should not deceive by making it appear that they are of minor importance—thrown in for good measure, as it were. Any one of them may be sufficient to turn a loss into a profit on work of magnitude.

The young civil engineer, whether before graduation from college or afterward, will find that an analysis of the cost of each item of work which comes under his observation, is the best possible training for him, even if he intends to be a designing engineer only. If he is a rodman on a survey he should keep records of progress on each kind of work so that he will be able to judge the efficiency of men working under him in the future when he shall himself be in charge of a party. If he is an inspector on construction he should attempt to record daily progress of the work, and of quantities of materials used; for thus he will discover the difference between good and poor designs of structures. He will learn that some of the greatest engineers have made the greatest blunders in economics; and this, if he is of the proper engineering metal, will not puff him up with an idea of his own superior insight, but will lead him to think with greater thoroughness. He will thus come to see that specifications are as important as the design itself—indeed, that they are part of the design, and that it is fatal to good engineering to copy a specification without weighing the dollars and cents effect of every word and phrase. He will see that there is more than strains and stresses in the design of a bridge, and more than coefficients of friction in conduits and canals.

Why Daily Cost Records Are Essential.—In a vague way many contractors realize the imperfection of the present common method of ascertaining costs of items of work. The common method, it should be stated, is to charge up against earthwork, for example, all the expenditures incurred in loosening, loading, conveying and placing the earth. The accounts are balanced once a month, so that when the engineer's monthly estimate of earth yardage is received, it is necessary merely to divide the total expenditure on earthwork by the total yardage to ascertain the cost per cubic yard. So with every other item; and each of the several items may be subdivided into as many subitems as seems desirable.

This common method of cost recording involves simply keeping the time of the gangs of men working on each class of construction, no effort being made to find out the daily output of each gang. There are certain classes of work that are easily measured each day, pipe laying, for example, and many contractors require the time-keeper or the foreman to record daily progress on such work; but, for the most part, construction work is not measured up daily, or even weekly, but only once a month. Even then the "estimate" is more apt to be a guess rather than an actual measurement. At best this common method serves only one object, and that is the least important object of cost keeping, namely, to indicate whether the contract prices are too low or too high. Scarcely any light is thrown upon the vital question of efficiency of men and plant; and, even when the monthly returns do indicate an unreasonably low output, the finger of the manager usually can not be laid upon the cause. Therefore to secure the most important advantages of cost recording, a system must be devised that will give daily records of progress. I am aware that many experienced men will be tempted to read no further, believing that the realm of theory and idealism is about to be entered by the writer. However, some encouragement may be given by stating that no system will be described that has not been in actual use long enough to establish its practical value.

Without a daily record of work done, the foreman and the men feel at liberty to work fast one day and slow the next—fast when the general manager is about; slow when he is

away. The work moves by fits, and the reactions of slowness that occur after the spells of activity are generally so prolonged as to more than wipe out all gains due to unusual diligence. Then, again, it is much easier to make excuses for failure to have made satisfactory progress, when the excuses have to be made only once a month than when they must be made once a day.

The day is the unit of pay for work done, and it should be the unit in which the work is measured, if satisfactory attempt is to be made to secure a fair return for the wages paid.

Records Should Show Outputs of Individuals.—The ideal system of cost keeping would show not only the daily output on each class of work, but the individual output of every worker. But there are many classes of work involving the cooperation of several men, making it impracticable to obtain a record of the work done by each. Then the aim should be to divide the forces into gangs, each gang having its special work which can be measured and recorded daily. Usually it is desirable to put each gang under a foreman who is held responsible for its output. In many cases it is sufficient to select one of the workers as the boss of the gang, but a working boss who assists the other men in everything they do. The aim in any case is to secure a gang working as a unit, with some one man in charge of the unit and responsible for its output. Then if the work is such that the output of each man in the gang can be measured separately, the most perfect system of cost recording can be established. To indicate by an example what can be done, let us take a gang of 12 men laying a slope-wall paving, all laboring in the usual helter-skelter way together, working individually at times, and at other times assisting one another in placing large stones. A foreman is in charge of this gang and reports weekly progress. The gang appears to be organized, but in fact it is only partly organized, since it is possible to secure the daily output of every mason and dispense with the foreman. To organize this gang the first step is to divide the slope into lots by means of "profile strips" nailed to small posts driven into the ground. The bottom of each of these strips is exactly level with the finished face of the proposed slope-wall, so that a cord, stretched from strip to strip,

will give a true line to work to. The profile strips are set 13½ ft. apart, so that every lineal foot on the strip means ½ cu. yd. of slope wall, if the wall is 1 ft. thick. Each mason is assigned to one lot, between two profile strips, and the lots are numbered consecutively with red chalk marks on the posts. The profile strips are of 2 × 4 dressed pine, painted with foot marks, so that a time-keeper can see at a glance the height to which the wall in any given lot has reached at the end of the day. There is no measuring to be done after the strips are nailed in place, yet the time-keeper and the masons themselves can keep a perfect record of daily progress. After the work has been under way a short time, it will be evident that a laborer to every two masons, say, will be necessary to deliver stone down the slope. The gang is now organized, the foreman is put at other work, and results are awaited. At first the average output is but little better than before, but certain of the masons do much better than the average. Their wages are then increased somewhat, and perhaps two or more of the slower masons are discharged. Immediately, if there are no unions to interfere, the output of the men increases. At the end of a week I have had the average yardage increase 50%, and individual yardage increase much more, the quality of the workmanship remaining as before. The men receive higher wages and the contractor increases his profits, both by virtue of the greater output and by reducing the cost of supervision. I have been away from such work, after organizing it, for two weeks at a time, without a foreman in direct charge, yet the output has not fallen off. This is the great advantage of recording the daily output of individual workers.

Difficulty of Measuring Daily Output.—There are three general classes of contract work that are easily measured; (1) work on single units; (2) work that progresses along a straight line; and (3) work that progresses over an area between two straight lines. We have just had an example (slope-walling) of the last named class. Street paving, road graveling and macadamizing, some kinds of painting, plastering, roofing, and the like, are other examples of work that can be divided into lots or blocks.

There are a good many examples of linear work, such as

track laying, pipe laying, tunneling, placing moldings, some kinds of ditch and trench work, placing curbs, etc.

Of work on single units, which need but to be counted, there are innumerable examples, such as erecting fence posts and poles, hanging doors, pile driving, hauling loads of a given size, etc.

When we take these three classes of work that are easily measured, we have left comparatively few classes that are measured with difficulty. Still enough are left to be a source of worry to the man who is installing a cost recording system. Nearly all massive work that is measured by the cubic yard, such as masonry and excavation, requires careful thought on the part of him who is trying to secure daily progress reports. Work on timber and structural steel is also difficult to measure daily, but I believe that no class of work is so complex that some satisfactory method of daily measurement can not be devised. It is the devising of a simple and practical way of measuring the daily output of the men that will test the ingenuity of the contractor or engineer in charge.

We shall now consider a few of the devices that have been successfully used in securing daily measurements of output.

The Unit Method of Measuring Output.—The ordinary foreman is not an engineer or even a fair mathematician. Often he can not write clearly. Any system of daily cost keeping that does not take this fact into account will be a failure. With this in mind, the aim should be to make the method of recording progress so simple that scarcely any mental effort is required on the part of the foreman, or time-keeper, or workman who records the daily output. It is desirable that not even a tape line be used by the recorder, and that he be not required to compute the length, area or volume of the work done. How, it will be asked, can this end be attained?

Many kinds of work can be divided into units of equal size. Thus, we have already seen that slope wall paving can be divided into strips, 1 ft. wide and 13½ ft. long, each containing a certain fraction of a cubic yard. These strips can be so marked that anyone capable of reading figures can measure at a glance the daily progress.

On macadam roadwork, I have found it desirable to set stakes every 20 ft. along the edge of the proposed macadam, marking each 100-ft. station, and each intermediate stake with its proper "plus." Thus the 5th hundred-foot stake is Station 5. The first 20 ft. stake beyond Sta. 5 is marked 5 + 20; the next is marked 5 + 40; and so on up to Sta. 6. The engineman on the steam roller can enter on a card, at night, the station and "plus" to which the broken stone has been laid. In the same way sewer trenching and pipe laying can be marked, placing the "plus" stakes 10 ft. apart if desirable. The object being to relieve the foreman or time-keeper of the labor of using a tape to measure up the daily progress.

There are few classes of work more difficult to measure daily than brick buildings, and concrete-steel buildings, due to the numerous openings and irregularity of forms. In concrete-steel building work there are various columns, girders, floor arches, etc., each containing amounts of concrete and steel not readily calculated by any ordinary foreman or time-keeper. But it is possible to give each separate type of column or girder a letter or a number, or a combined number and letter, so as to distinguish it from other similar columns or girders—of greater or less size. Take the blue print of the building, and with a red pencil divide the concrete into units, preferably separating the units where expansion joints or other joints occur. Then, for example, reserve the numbers up to 100 for the first floor, 101 to 200, for the second floor, and so on; marking columns C_1, C_2, etc., on the first floor; similar columns on the second floor being marked C_{101}, C_{102}, etc. Having thus divided all the concrete work into units, make small blue prints, about as large as a postal-card, showing the outlines of each unit and its number. The man in charge of a certain part of the work is furnished with the small blue-prints of the units he is to build. He is also furnished each day with a ruled card on which he enters the number of each kind of units built by him, and the number of men and their time on each unit. This card is turned in at night, and posted in a cost record book by the book-keeper or time-keeper, who simply multiplies the number of units by the recorded yardage in each unit. Thus the foreman makes no measurements, or computations, but simply counts the units of work

done and records them. This unit recording system is the secret of the success of several well-known firms.

On heavy dimension masonry I have applied the unit system, in a modified form. The time-keeper, a young engineering graduate, was required to measure the dimensions of each block of stone as soon as it was dressed, and paint a distinctive letter and number on an end face. This reference mark was entered in a note book opposite the dimensions of the stone. As fast as the stones were laid in the dam each mason in charge of a derrick gang was required to mark on a card the letter and number of each stone. When this card was turned in at the end of the day, it was possible to compute the yardage of cut stone laid by each gang by referring to the time-keeper's records giving the dimensions.

In like manner records of heavy timber work may be kept by marking every stick of timber; and there is no reason why this same method can not be applied to structural steel work and to a great variety of work where large pieces are handled.

Recording Output by Weighing.—Where the materials are small and irregular in form, it often happens that the most satisfactory method of keeping records of output is by weighing each butcketful, car, wagon or skip load. This method has long been in use at coal mines where every car is numbered, and is weighed before dumping. On contract work, such as macadamizing, for example, each wagon load may be weighed, if the amount of the work warrants the purchase and use of platform scales. It is usually considered sufficiently exact, however, to measure the size of a few loads, and simply count the number of loads. However, loads often vary so greatly in size that this method of counting loads becomes very unsatisfactory. This holds true particularly of loads of quarried stone, of earth loaded by steam shovels, and the like. In such cases the contractor should seriously consider the advisability of weighing each load.

One of the most difficult classes of construction work to measure daily is rubble masonry. Yet I have found two very satisfactory methods of recording the work done by each derrick gang. One way is to use wooden skips that are loaded at the quarry with stone, put upon cars

and transported to the work. Each skip is provided with a clip for holding a brass check. The checks are numbered serially, and the weight of stone corresponding to each number is entered in a book; for before delivery to the masonry derricks each skip is lifted by a derrick, placed on a scales and weighed. It would be practicable to provide a large spring balance for weighing instead of using scales. The mason in charge of the derrick gang removes the brass check from the skip and keeps it, entering its number on a card which is turned over to the time-keeper at night, together with the brass checks. Thus it is possible quickly to ascertain the number of tons of rubble laid by each gang.

Where the job is so small as not to warrant the slight extra expense of weighing the stone, a very satisfactory method is to require the boss of each derrick gang to record the number of skips of mortar used, also the number of skips of spalls. No attempt is made to record the amount of rubble stones; but this amount can be estimated quite accurately if record is kept of the mortar and spalls, for, in any particular class of rubble work, the mortar forms quite a constant percentage of the masonry. However, care should be taken to furnish the spalls in skips of uniform size, as well as the mortar, for otherwise the boss will be tempted to use pure mortar in order to make a good showing in daily output of masonry. Mortar is expensive when mixed rich in cement, whereas spalls are cheap, even if broken by hand especially for the purpose, so that it is desirable to displace as much mortar by spalls as possible. Therefore a record should be kept of the spalls as well as of the mortar. By occasionally measuring up the wall laid, the percentage of mortar and spalls to the total wall yardage can be ascertained, and from this percentage the daily progress of the work can be computed.

Record Cards Attached to Each Piece of Work.—In doing machine-shop work it is often necessary to have one piece of metal pass through the hands of several different workers. For example, one man may drill holes of a certain size, another man may drill holes of another size, still another man may thread the holes, and so on. In such a case it is common practice, where careful cost records are kept, to provide a card that is attached to each piece or each lot of pieces. In blanks provided on the card, each worker enters his number, and the number of hours and minutes

spent by him doing a specified kind of work on the piece. A modified form of this method is to attach a card or a brass check to each piece, giving a serial number and letter to the piece. Each workman on the piece notes its number on his own record card, and opposite this number he enters the amount of time spent on the piece.

While this method of recording output can not be as frequently used in engineering contract work as in machine shop work, it should not be overlooked by the general contractor. It might well be applied to timberwork where one gang of men bores the holes, another gang saws and a third gang "daps" or adzes the sticks, and so on. It is desirable always to assign different kinds of work to different men, not only because the time usually lost in changing tools may be saved, but because men become more expert when they do one class of work only. The record card facilitates the differentiation of labor into classes, and is, therefore, a great aid in increasing the output of a given number of men.

Record Cards Used With a Conductor's Punch.—Workmen with rough, tough and grimy hands do not take kindly to keeping records in writing. I find, therefore, that the common "conductor's punch" can be used to good advantage in tallying the output of many classes of work. By using punches that punch holes of different shapes, it is easy to make one card show several different records. In Engineering News, Mar. 27, 1902, I first described the use of the time record card shown in Fig. 1. This card was designed for the purpose of recording the work of each team engaged in hauling broken stone. The diamond-shaped punch shows that the team started on its first trip at 7.05 in the morning, and the cross-shaped punch shows that it started on its return trip at 8.20. Each teamster is given one of these cards every morning, the number of the team, and the date appearing on the card, also the location of the work and the length of haul. Two men, one at each end of the haul, are provided with conductor's punches of different shapes. They are also furnished with cheap watches, and are required to punch the card, to the nearest five minutes, at the time the team leaves. If the haul is short, a larger card is used so that the nearest minute may be punched instead of the nearest five-minute interval. These cards serve two very useful purposes: First, they

spur the drivers to do a good day's work, because of the knowledge that their work is being recorded; second, they enable the foreman or manager to discover where time is being unnecessarily lost. For example, I discovered by the

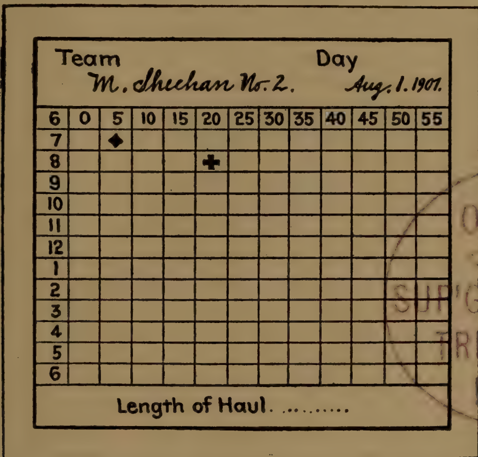


FIG. 1.

use of these cards that much time was being lost at the rock bins, due to the flat slope of the bin bottom and the poor design of the bin chute. By a few changes at the bin much expensive delay was avoided. On long hauls delay in loading was unimportant, but on short hauls it was a large percentage of the total team time. The teams were all hired teams, and the drivers were not a very active lot of men. But the introduction of the record card increased the daily number of loads by 25%, without in the least overworking the horses.

The punch record card can be used to tally the number of batches of concrete mixed per day, instead of tallying by cutting notches in a stick or marking a piece of paper, as is commonly done. Where hand mixing is used it may even be well to have the foreman or the boss workman punch the nearest minute when the batch is finished; but on machine work this might take his attention too frequently so that it would be preferable merely to have the dumpman tally the

batch by punching a hole in a card without regard to the time.

There are innumerable uses to which the punch and the record card can be put, and it requires but a little ingenuity to devise a card suited to any given purpose.

Use of a Mimeograph for Printing Record Cards.—On small jobs it frequently would not pay to have record cards printed; moreover, there is usually delay in getting job press-work done. I have found the most satisfactory solution of this problem of printing record cards to be the use of a device called the "mimeograph," an invention of Edison. It consists of a frame for holding a stretched sheet of paraffined paper which may be laid upon a block of steel that has been cross-ruled with very fine lines. A "stylus," or pen, having a blunt steel point, is used for writing or lettering. The stylus is pressed rather hard upon the paraffined paper, and the little sharp teeth of the steel block cut fine points through the paper wherever the stylus comes in contact with the paper. Having written or printed as much as is desirable, or as the sheet of paper will hold, the steel block is removed and for it is substituted a card (or paper) that is to receive the printed words. A small roller, inked with printer's ink, is then run lightly over the paraffined paper. The ink passes through the small holes and thus prints the letters on the card below. Then another card is substituted and the rolling process is repeated, and so on until as many dozens or as many thousands of cards are printed as are desired. After the paraffined paper has once been lettered, the work of printing cards can be done almost as fast as with a hand printing press, and the results are excellent.

A later development of the mimeograph consists of a cylinder or drum, and an automatic inking device, so that the cards or sheets to be printed can be run through at a remarkably fast rate. An ordinary type-writer is used to letter the paraffine paper, instead of using the steel stylus above described. Very neat work is thus produced with great rapidity.

A mimeograph can be purchased through any dealer in stationery, and at a very moderate price.

Automatic Time Stamps,—A machine often used in large machine shops is an automatic time stamp. For contractors' use the type of stamp manufactured by the

Perry Time Stamp Co., Chicago, Ill., is very satisfactory. The clock automatically regulates the stamp so that it records the year, the day of the month, the hour, and the nearest minute. The operator simply inserts a card and presses down on the stamp, and a full time record is printed on the card. Such a machine might well be used for recording the output of every batch of a concrete mixer, every train load of material, etc. Thus accurate record could be kept of the cause of delays, as well as the length of time required to make a trip. A boy can operate the machine without a possibility of error as to the exact time.

At all large factories a time clock is used to register the time of arrival of each workman. There are many classes of contract work where the time clock can also be used to advantage.

Time Cards and Time Books.—Through any stationery store time books can be bought that are ruled and lettered to suit most classes of contract work. The time-keeper enters the name of each man and assigns him a number in the book. On large jobs it is wise also to provide a brass check that can be pinned to the clothing of each workman, so that his number is visible at a glance. The home addresses of common laborers are seldom entered in the time books, but I have found it desirable always to record home addresses of all men, and particularly the permanent addresses of skilled workmen and foremen. A few postal cards will thus enable one quickly to gather together a gang of skilled men for a new job. It is wise also to have a directory book for entering the names of good foremen, whether they be men that you have employed or not; and a few brief remarks concerning each man's fitness for particular classes of work should be entered. This assists also in identifying men whose names have slipped the memory.

Time books are very often ruled so that the job the men are working on cannot be entered opposite each man's name. It is necessary then to reserve separate pages for each job. Then if a man does several different kinds of work on one job, as many different lines are reserved under his name so that the hours and fractions spent by him on each kind of work can be recorded. In that case the foreman is provided with a time-book from which the time-keeper makes abstracts when he goes the rounds. A

more satisfactory way is to provide the foreman with cards on which are printed or mimeographed the different kinds of work, and on each card is marked the number assigned to each workman, and the time spent by him on each class of work. Such a card for roadwork is shown in Fig. 2.

MAN NO.		CONTRACT NO.	
Date,	Foreman,		
Spreading Stones,	hours.	Station	to Station
Trimming Slopes,	"	"	"
Digging Ditches,	"	"	"
Grading Road,	"	"	"

FIG. 2.

It will be noted that the exact location of the workman on each class of work is given by entering the numbers of the Station stakes between which his work is going on. Such cards are far more satisfactory than any time books when it comes to an office summarizing of the work done. Moreover, the loss of a time-book might completely destroy the value of a set of records.

Another form of time card (one that is used by the Aberthaw Construction Co., of Boston) is shown in Fig. 3. The name or number of each workman is entered in the first column. On the back side of the card the spaces for names, etc., are continued so that 27 names can be entered on the two faces of the card. The time in hours spent by each workman on each class of work is entered in hours

JOB NO................ LOCATION....................................

DATE.................. 190........

Name of Workman.	Time. Carpenter.	Time.	Time. Concrete	Time.	Time.	Rate.	Am't	Put at head of proper column or against each name index of work performed.
1.........Foreman								State each kind of work done. Am't of Cem. and Glass used.
2................								Weather......................
3................								Temperature ....
4................								
5................								
6................								
7................								
8................								
9................								
10................								
11................								
12................								
13................								Approved

FIG. 3.

In accepting this card, I declare that I am a citizen of the United States.

NAME.. NO...........................

CONTRACT... OCCUPATION..................................

Week Ending PAID. DISCHARGED. Week Ending

Sun.	Mon.	Tues.	Wed.	Thur.	Fri.	Sat.
½	½	½	½	½	½	½
1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7
8	8	8	8	8	8	8
9	9	9	9	9	9	9
10	10	10	10	10	10	10

TIME CARD.

G—— & G——

Engineering Contractors,

Rate per Hour.

5	7½	10	12½	15⅝
16	20	37½	30	35

Sun.	Mon.	Tues.	Wed.	Thur.	Fri.	Sat.
½	½	½	½	½	½	½
1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7
8	8	8	8	8	8	8
9	9	9	9	9	9	9
10	10	10	10	10	10	10

FIG. 4.

and fractions. Certain "index" letters, or key letters, are used to designate each class of work; B, for example, may indicate a concrete base, and P may indicate a concrete post; E may indicate a certain kind of excavation; and so on. This makes a compact card adapted to a great many uses. After visiting work being done by the Aberthaw Construction Co., and noting the splendid output of their workmen, I have been more than ever convinced that "system pays," even if it costs a little more for bookkeeping.

In order to avoid disputes on pay day, I devised the form of card shown in Fig. 4. Each workman is provided with one of these cards which he keeps until pay day. This card was devised for work on which pay day came every second week. The rate of wages is punched with a conductor's punch, likewise the number of hours and the nearest half hour for each day. The time-keeper or foreman punches every man's card at the end of the day, and at the same time enters the number of the man and his hours in the time-book. If any dispute arises as to the number of hours worked the dispute must be settled then and there, for on pay day no claims for extra time will be listened to. This does away entirely with pay day disputes, which is a very satisfactory feature. The card also serves to check the time-keeper's records. Moreover, it makes "padding" of payrolls more difficult, and facilitates detective work if "padding" is suspected. The card also serves as a discharge slip; for, when a man is discharged, the foreman punches the hours that he has worked and he also punches a hole through the word "discharged." When the man presents the card at the office he is paid; the card is kept as a voucher, and a hole is punched through the word "paid."

Cards for Recording Materials Received.—The card system has been successfully used for recording the distribution of materials and supplies used on a job. Fig. 5 shows a card used for steam shovel work in rock. All materials sent from the store house to any particular machine or place are recorded on the card.

Figure 6 shows another form of card, one of which is issued daily to each foreman in charge of concrete work. The number of barrels or bags of cement and the brand, the number of loads of sand, etc., the number of pounds of crushed stone, the number of feet of lumber, the number of bars of steel and the size of the bars, etc., are all recorded

SUPPLY REPORT NO. 1. ....190....

	Drillers.	Pumps.	No. 1 Shovel.	No. 2 Shovel.	No. 1 Dinkey.	No. 2 Dinkey.	No. 3 Dinkey.	Cars.	Shop.	Little Hill.	On Hand.
Cyl. Oil....											
Eng. "											
Blk. "											
Waste.....											
Powder....											
Dynamite..											
Exploders.											
Caps......											
Fuse......											

FIG. 5.

Job No. **MATERIALS RECEIVED**

Date 190 **Foreman**

Size or Brand	From Whom Received	Size or Brand	From Whom Received
bbls.	Cement	bbls.	Glass
bags	"	bars	Steel
lds.	Gravel	"	"
"	Sand	"	"
"	Screenings	"	"
lbs.	Stone	lbs.	Lampblack
"	"	"	Oakum
lds.	Sand	"	Nails
ft.	Lumber		

FIG. 6.

on the front face of the card. On the rear face of the card a similar entry is made of all material sent from the job or left unused at night. This gives a check on the amount of materials used in the work. Each class of contract work requires a differently printed card, and a little experience is needed to show what form of card is particularly adapted to the work. Perhaps enough has been said to indicate the possibilities and the simplicity of the card record system.

Use of Slide Rules and Wage Multiplying Tables.—The office work of computing the cost of work may be greatly reduced by the use of a slide rule. Almost as fast as one man can read off the number of hours worked by each laborer and his rate of wages, an assistant can perform the multiplication with a slide rule. The results will be close enough for all practical purposes.

For computing pay-day wages, a multiplication table, giving the product of any given number of hours by any given rate of wages, may be prepared. The ordinary small tables published in the back of time-books are seldom comprehensive enough for general use. Having computed the wages for each man by the aid of a table, it is well to check the computation with a slide rule.

Recording Work by Minute Hand Observations.—It has often been said that short time observations prove nothing as to the efficiency of men or machines. This statement has been exceedingly misleading to those who have accepted it as a self-evident truth. When a short time observation does not include the common delays incident to shifting tools, to breakdowns, and the like, it may lead to a serious underestimate of the cost of work. On the other hand, when the so-called short time observation is made long enough to include the time spent in necessary rests, in moving machines, in repairs to plant, and the like, exceedingly valuable results may be obtained. When it is desired to find whether men are lazy, whether a foreman knows his business, whether the method of doing the work can be bettered, or whether the tool or machine is susceptible of improvement, there is no method to be compared with the method of timing work with the minute hand of a watch. Moreover, where it is desired to discover the effect on cost of varying the length of haul, of varying the kind of rock drilled, and the like, timing with the minute

hand is the only satisfactory way of arriving at definite conclusions.

In my book on "Rock Excavation" I have shown how such timing has enabled me to lower the cost of rock drilling, and to predict the cost of drilling in any given kind of rock under given conditions. In an editorial article in Engineering News, July 2, 1903, I have shown how minute-hand timing may be used to increase the number of piles driven daily by a pile driver. I have also shown, in the same article, that there is no economy in using a steam hammer on railroad trestle piling, because so little of the time is spent in actual hammering of the pile. In my book on "Earthwork and Its Cost" I have given rules for estimating the cost of earthwork, based upon numerous minute-hand observations, and checked by comparison with records of cost extending over months of work.

In a lecture* to the students of engineering at Columbia University I gave some suggestions on minute-hand timing that may be quoted with propriety:

"I would impress upon you that you should not wait until you are in responsible charge of work before you begin gathering cost statistics. Many of you will find yourselves before long in the position of inspector on some engineering work of magnitude, and the very magnitude of the work will probably discourage you in your determination to learn something about costs by your own observation. Let me assure you that you need not be in the least discouraged, that in fact you will probably be in a better position to acquire the most valuable kind of data than is the chief engineer himself. He, to be sure, will learn in a general way what each of the classes of work costs; but you, if you avail yourself of your opportunity, will learn in detail what certain parts of the work cost. I would sooner know every detail of the cost of a given kind of work on the New York Subway, for example, than to know in a general way what all the items cost, and let me explain to you why. Suppose that you determine to learn the cost of rock excavation where cableways are used to handle the excavated rock. You start by studying the cost of handling the rock with the cableway, and with your watch in hand, you note that at 9 : 15 : 10 (reading the hour, the minute and the

*Printed in The School of Mines (Columbia) Quarterly, July, 1904.

second hand) the bucket begins to rise from the pit; at 9 : 15 : 20 it is out of the pit and begins its travel along the cable; at 9 : 15 : 40 it has reached the dump; at 9 : 15 : 55 it has dumped; and so on until it has made the round trip. Thus you time in detail a large number of round trips until you have a fair average for each element. You measure the lift and the distance of travel, and you note the kind and size of engine used; and when the plant is shifted from one place to the next you ascertain the lost time and the cost of shifting. What, you may ask, is the use of going so minutely into details? The answer is simply this, that you may be able to predict the cost of future work where some of the details differ, as for example the lift, or the length of the haul, or the number of times the plant must be shifted for a given yardage of excavation. Without such detailed data you will be unable to predict accurately but will have to guess. It is just this kind of detailed information that the chief engineer very likely will not get, so that, in fact, with all his seeming advantage he may not be able to predict the cost of similar work, where conditions vary somewhat, with as great accuracy as you can. Indeed I venture to say that on one job, thoroughly studied in detail, it is possible for a young engineer to learn more about actual costs than the majority of engineers learn in a lifetime."

Having secured minute-hand records of the number of feet drilled in a given time by a rock drill, for example, the observer should check his estimate by talking with the drillers, the foreman, the contractor and the engineers. He will soon discover that these men often have but the vaguest idea of the time lost in changing bits, shifting machines, delays at blasting, etc., although they can give a reliable estimate of the average day's work of a machine. In a word, he will learn that these men, who think they know their business, are exceedingly ignorant of the essential details upon which profit or loss depends.

The most elaborate system of time records and bookkeeping cannot show what minute-hand recording will show. By this I do not mean to decry bookkeeping, but to make it evident that bookkeeping is only a part of a perfect system of cost recording. An essential part of the ideal system that I have in mind would be the frequent examination of every item of labor cost by means of a trained ob-

server equipped with a watch. If a stop-watch is not available an ordinary watch with a second hand will serve, and in many classes of work even the second hand can be dispensed with. An example will now be given to illustrate the method and value of a short time observation.

Before beginning the record, set the minute hand so that it points an even minute when the second hand points at 60. Suppose it is desired to time the drilling of a hole in a seamy mica-schist, using a steam drill mounted on a tripod. At 9:37 A. M. the driller is set up and ready to begin drilling a hole and exactly 30 seconds later he turns on the steam; then we begin our record:

9.37.30	Start.
9.49.20	Down.
9.51.20	Start.
10.00.40	Down.
10.03.40	Start.
10.09.40	Down.
10.13.00	Start.
10.14.40	Bit sticks.
10.24.40	After hammering the drill repeatedly, the driller is directed to break up some cast iron and throw it into the drill hole.
10.32.30	Drilling begins again.
10.45.00	Hole finished.
11.15.10	New hole started.

It will be seen that drilling started at 9.37.30, and that at 9.49.20 the full length of the feed screw was out, and that to drill farther a new bit had to be inserted. At 9.51.20 the new bit was in and drilling began again, after a delay of 2 mins. in changing bits. At 10.00.40 the second bit was down. Each successive bit, it should be stated, is usually 2 ft. longer than its predecessor. At 10.14.40 the bit sticks in the hole due to having run into a pocket of rotten rock. The observer might readily have predicted this sticking by noting the increased rapidity of penetration; for it took nearly 12 mins. to drill the first 2 ft. of the hole, and only 6 mins. to drill the 2 ft. just prior to the sticking. After wasting 10 mins. abusing the drill the driller finally removed the bit (at the direction of the observer), broke up a piece of cast iron pipe into hazel nut sizes, and threw two handfuls of the iron into the bottom of the hole. Drill-

ing was resumed at 10.32.30, and the last 2 ft. were completed at 10.45.00. At 11.15.10 the driller started another hole, having spent more than 30 mins. shifting the tripod and drill.

What do we learn from this observation, assuming it to be a fair average. First that the driller was slow in changing bits; second, that he was very slow in shifting his tripod; third, that the driller was ignorant; fourth, that the foreman was equally so; fifth, that fragments of cast iron completely overcome sticking of bits in this rock.

We know that the driller was slow, because other similar observations have proved it possible to change short bits in much less time than 3 mins., and, since the driller has an easy time of it while turning the crank, he can work rapidly without exhausting himself when it comes to changing bits or shifting the machine. We know that both driller and foreman were ignorant, for broken iron should have been provided ready to use in case of sticking of the bit. We conclude that it will pay to assign a man to measure up the footage of hole drilled by each driller every day, and to offer each driller a bonus for every foot of hole drilled in excess of a stipulated minimum.

The foregoing is a record of fact and not of theory. On a large contract job the author secured an increase of 45% in the daily footage of each drill by taking just such observations as the above.

Labor unions often prevent the adoption of the best plan for increasing output, but they can not prevent a manager from knowing where the losses are occurring. There is no excuse, therefore, for failure to study machine work in the manner above outlined.

I have found it of great advantage to time in detail the work of cableways, derricks, steam shovels, concrete mixers, dinkey locomotives, pile drivers and other machines used on contract work. Even the output of men working with hand tools can be profitably studied in the same way. I have timed the number of shovelfuls of earth handled under different conditions with a view to ascertaining the effect of changed conditions, and the effect of using larger shovels. However, the greatest gains from minute-hand timing occur when it is applied to machines operated by power rather than to hand work.

It is desirable in all cases not to let the workmen know

that they are being timed. When men are working in the open air, an observer can often use the telescope of a transit or a pair of field glasses to good advantage. In shop work, or underground, where the observer must be near the men, a convenient way of timing any detail of work is by counting. One can soon learn to count with regularity, and thus dispense with a second or minute hand. Other methods of ascertaining the time of doing work without being observed will occur to any who gives thought to the matter.

Cost records of daily output, when properly analyzed, are of great value; but let no manager of men and machines neglect to have itemized short time records taken at frequent intervals.

How to Prepare Estimates and Bids.—In estimating a unit price for any kind of work, contractors often place too much reliance on published prices for similar work. There are seven serious sources of error in so doing: (1) The conditions vary greatly in places but a few miles apart; (2) rates of wages also vary widely, being, for example, higher in large cities than in small cities or in the country; (3) specifications and the interpretations of identical specification clauses by different engineers vary greatly; (4) contractors inexperienced in the particular work in question often bid prices altogether too low; (5) the bidding prices may be purposely unbalanced, being too high on certain items and too low on others; (6) a unit price that is fair for a large job is generally too low for a small job; (7) a contractor already equipped with a plant can often afford to bid lower than the contractors not so equipped.

While previous bidding prices should be used as a guide, they should never be relied upon implicitly if the work is of any considerable magnitude. Each item should be estimated in detail, and this estimating should be done systematically to avoid some serious omission. The cost of any item of work may be divided into five parts:

1. Development expense.
2. Plant expense and supplies.
3. Materials.
4. Labor.
5. Superintendence and general expense.

Development expense includes the cost of making roads,

delivering and installing the plant, draining the site of the work, salaries of foremen and others on the idle list pending the beginning of work, and all expenses involved in getting ready to build the structure. On small jobs this item of development expense is often a very large percentage of the total cost; and on large jobs it seldom can be neglected in estimating probable unit costs.

Development expense has to be estimated for each particular job, by securing freight rates or estimates for carting, etc. In some cases it includes temporary road building, installing pipes for water supply, etc.

Plant expense includes interest and depreciation on all tools, machines, buildings, stored materials, trestles, falsework; also the cost of maintaining the plant during its operation, new parts, fuel, oil, etc.

Materials include only such materials as actually go into the finished structure, and the wastage of materials due to breakage in handling or sawing and shaping. The cost of materials includes freight and hauling to the site of work.

Labor includes all skilled and common labor, except foremen, clerks and office men.

Superintendence and general expense includes foremen, managers, timekeepers, watchmen, bookkeepers, supply clerks, rents, taxes, traveling and entertaining expenses, stationery, etc.

To the experienced contractor an enumeration of these items may seem unnecessary, but it is indeed surprising to see how often inexperienced contractors err through failure to consider all of these items. Engineers, and not always young engineers, are prone to omit development and plant expense, either in whole or in part, from their estimates of cost.

Plant Expense; Interest and Depreciation.—Plant expense is commonly underestimated. First it is necessary to consider the time limit allowed for the work. Then a plant must be figured upon that will perform the work at least 20% within the time limit, making also liberal allowances for bad weather delays, as well as for delays in delivering and installing the plant, and delays due to breakdowns. Use with great caution the figures of output given in most catalogs; they are almost invariably based upon ideal conditions, and not infrequently are wholly de-

ceptive. Even where the output of a machine is correctly stated, remember that such an output may not be possible in your case, due to inability to get materials to the machine or away from it. Consider always the limiting factor. A derrick, for example, may be able to handle 200 cu. yds. a day, but if it serves a few men working in a confined space, its actual output may not be 30 cu. yds. Time and again this self-evident fact has not been evident to the inexperienced man.

To give another example, suppose the work is rock excavation. Do not guess at the number of rock-drills required; but estimate the probable spacing of the drill holes in the given kind of rock, and from this calculate the number of cubic yards of rock each drill will break daily on a basis of, say, 50 ft. of hole drilled per machine per shift. Knowing the time limit, compute the number of drills required; and, knowing the number of drills, compute the boiler power required. Guess at nothing. If you have no other data, secure, by letter, some estimates of output from the large and old manufacturing firms, whose estimates are frequently very close to the truth.

Having liberally estimated the size and kind of plant required, and having secured quotations on the plant, charge the full cost of the plant up to the job to be done, and determine how many cents per yard, or per other units involved, are thus chargeable to first cost of plant. This will give a maximum charge, and it is well to know the worst. But if the full cost of a plant is charged to a small job, some other contractor will probably get the work. Go, therefore, to a dealer in second-hand machinery, and ask him to name a fair price on a second-hand plant such as yours will be when you are through with it. If you can secure a tentative bid on the machinery, you will have a fairly reliable estimate of its salvage value. In most cases you can form some estimate of the salvage value, by finding what second-hand plants are selling for. If you are still afraid that your charge for depreciation will be so high as to lose the job, there is left just one safe way of estimating, namely to secure a rental quotation. There are many firms who make a business of renting contracting plants, and such a plant as is wanted can usually be rented for a daily or monthy price that includes ordinary wear and tear. The longer the plant is to be used the lower the

daily rate of rent, therefore be careful to secure a sliding scale lease. A hoisting engine and boiler may be rented for, say, $2 a day, if the period is to be 30 days; but, for each added 30 days, there should be a reduction in the rate, down to, say, $1, beyond which no further reduction is given. The reason why such a sliding scale can be secured is briefly this:

The season for contract work is usually limited; road work, for example, is limited to the summer and fall months. Most of the contracts are awarded at an early date, so that if a plant remains unrented well into the season, the chance of renting it falls off rapidly. Periods of idleness between times of rental soon cut down the net income from a plant, yet interest on the investment goes on uninterruptedly. If these periods of idleness can be reduced the owner of a plant can afford to accept a lower per diem rate of rental, yet be a gainer at the end of the year.

Then, too, there are some seasons when contractors and their plants are abundant, and work is scarce. The revenues from such plants are then correspondingly small.

I have found that a roadmaking plant does not average 100 days actually worked per year. A 10-ton steam roller costs, say, $2,500; and, if interest is charged at 6% per annum, we have $150 to be distributed over 100 days—not over 365 days, as many engineers have done.

Depreciation, of course, does not go on as rapidly when a plant is idle as when working, provided the plant is properly housed and cared for; but the housing and the care cost money. Moreover, many kinds of machines become obsolete in a few years, so that depreciation cannot be said wholly to cease while the plant is idle. All the annual depreciation and all the cost of housing and caring for the plant should be distributed over the average number of days actually worked. If, on a 10-ton steam roller, the annual depreciation is $200, we have $200 ÷ 100, or $2 per day worked; and if we add to this the $1.50 per day charged to interest, we have a total of $3.50 per day worked. Now, such a charge should be made by the contractor even where he uses his own roller; indeed, he may be justified in making a greater charge, for, if he does not have the $2,500 invested in the roller, his working capital is so increased that he may take a larger contract.

It may be asked why the interest and depreciation are

distributed over the days actually worked. The answer is that the output of the plant is usually estimated as so and so many units per day, and that, in consequence, all costs should be reduced to the same basis.

For years the most absurdly low estimates of plant expense have been made by engineers, because of the lack of a business training in so many of our engineering colleges.

When operating a plant the item of current repairs cannot always be separated from depreciation. Perhaps it is best to consider the replacing of all parts that wear out rapidly as being current repairs. Then only the heavier and more expensive parts may be said to depreciate.

Of course depreciation is a variable item, even in the parts of the same machine. A dredge hull may have a life of 20 years, while the bucket of the dredge may not last 2 years. Where the depreciation is due mostly to rust or decay the depreciation is best expressed in percentage per annum; but where the depreciation is due mostly to wear the depreciation should also be expressed in terms of the work done. A cableway, for example, may last 2 years if it handles only 25,000 skip loads per year; but if 100,000 loads are handled in a year, two cables will be worn out. Depreciation, when stated in percentages per annum, must be used with caution.

Cost of Fuel for Engines.—I find it convenient to estimate the amount of coal for hoisting engines, and the like, as follows: Allow one-third of a ton of coal for each ten horse-power per ten-hour shift. This rule holds good for most of the engines, up to 80 HP., used by contractors.

Cost of Superintendence and General Expense.—The cost of foremanship on contract work seldom exceeds 15% of the cost of labor, and it seldom runs much below 5%. If one must guess, perhaps 10% is a fair average. These percentages include the salaries of foremen only. The salaries of general superintendents and office men, and all office expenses are preferably called "general expenses" or "fixed expenses." General expenses seldom amount to less than 4%, and on small, intermittent job work they may run much higher.

Percentage to Allow for Contingencies.—After estimating the probable cost of every item of work as closely as possible, including superintendence and general expenses, a percentage should be added for contingencies. A

very common allowance is 10%; but no such rough guessing is indulged in by either a careful engineer or by an experienced contractor.

Contingencies is an item used to insure against oversights and ignorance. On work where sub-contracts can be let at once for the materials, there is practically no risk taken on materials, hence there is no justification, on the part of the contractor, in making an allowance to cover contingencies on materials. The engineer who designs a structure may be justified in making such an allowance to cover possible bills for "extras," but not otherwise. On the other hand, it is often wise to make an allowance to cover possible inefficiency of laborers, or possible strikes, or possible rise in rates of wages; for, after estimating the average cost of labor on a given structure, there is always some risk of exceeding the average, for some unforeseeable reason. On large jobs both the designing engineer and the contractor are justified in adding from 5 to 20% to estimated labor costs to cover contingencies. If the price of materials has been steadily rising, then a study should be made of price curves extending over several years in order that some rational allowance may be made for the probable rise in prices of materials before they can be sub-contracted for. If, on the other hand, prices are on the downward curve, a contractor may feel justified in bidding lower than he otherwise would. The best way to arrive at an allowance for contingencies is to keep a full record of the estimated cost of each item of work, and subsequently compare it with the actual cost. In this way it will be found that there is seldom a job on which every item of cost can be accurately predicted.

Percentage to Allow for Profits.—In a number of editorial articles in Engineering News, I have discussed this subject at length. The common method of adding uniformly 10 or 15% for profits is open to serious objections, among which are the following: (1) The percentage to add for profits on materials should usually be less than the percentage to add for profits on labor, particularly when profits and contingencies are lumped together; (2) The time element and the size of the job should always be factors in considering profits, for profits are, strictly speaking, the salaries of the contractors; (3) The number of dollars' worth of contract work that can be secured and handled each average year must be considered, for the reason just

given; (4) The percentage for profits is often made to include interest on plant and on cash capital invested, and, if so, there is added reason for not using a uniform percentage like 15%.

That there is need of calling attention to these elementary principles is apparent when one notes erroneous statements found in many text-books.

On materials, such as brick, timber and steel, that can be bought by sub-contract immediately after the award of the main contract, one may estimate a low profit, say, 10 or 15%; but on labor the profit should usually range from 15 to 25%, or even higher if contingencies are included in the percentage allowed for profits.

On contract work that can be done only during a few months of the year, and especially on work requiring a large investment in plant, such for example as macadam road work, the percentage of profits must usually be above the average of the percentage on work that extends over a longer period. If engineers fully realized the importance of this fact they would be at more pains to award all highway contracts early in the spring of the year, so that a longer season would be available than is now the case.

List Prices and Discounts.—The prices of machines and materials printed in catalogs are usually subject to discount. On some standard materials, like vitrified pipe, the discount is often so large as to make the list prices of no value at all in preparing an estimate, unless the estimator knows approximately what the discount is.

Discounts are often quoted thus: 80% and 10%, or "eighty and ten." This does not mean that the discount is 90%, but that 80% is first to be deducted and then 10% is to be deducted from the discounted price. Thus, if the list price is 80 cts., deducting 80% makes the discounted price 16 cts. Then deducting 10% from 16 cts. leaves the net price of 14.4 cts.

In considering the purchase of a machine, always consider the net prices of the parts that must be renewed most frequently. A machine cheap in first cost is often dear in maintenance, due to the high prices charged for renewal parts.

Insurance of Workmen.—There are a number of casualty companies that make a business of insuring a contractor against accidents to workmen and against accidents

to the public. The following extract from my lecture to the students of engineering at Columbia University in 1903, bears upon this point:

"I learned by this accident two things: (1) Never to omit an allowance for accidents and other unforeseen contingencies; (2) never to neglect to insure the workmen. I shall digress to say a word about insuring laborers. Up to that time, I had supposed that if laborers were to be insured, it could of course be done by taking out a separate accident policy for each man—quite an expensive procedure as you doubtless know. After the accident I learned upon looking into the matter that a blanket policy covering all the men can be taken out, and that the premium is a given percentage of the pay roll; thus on earthwork you may insure all your men for less than 1% of the pay roll. This insurance does not give to each man a weekly stipend in case of accident, or to his heirs a designated sum in case of death. What the insurance company does do is to protect the contractor by assuming all liabilities from claims made by injured workmen or their heirs. The insurance company limits its liability, however, so that in case a number of men are killed by one accident, the contractor may have to stand part of the damages. No matter how safe the work seems to be, a contractor should never neglect to take out a pay roll insurance policy. Many a contractor, just starting in business, has been ruined through failure to insure against accident."

A Schedule of Items of Cost.—In preparing an estimate of unit cost there is always danger of omitting some important item. To avoid such an omission I find it desirable to compare my estimates with a schedule of items, such as follows:

1. Cost of temporary roadways.
2. Cost of right of way through farms, etc.
3. Cost of clearing and grubbing the site.
4. Cost of snow removal and draining the site.
5. Cost of the site.
6. Cost of sheds, barns, offices, etc.
7. First cost of tools and plant.
8. Cost of delivering and installing plant.
9. Cost of supplies, including explosives, water, fuel, oil and current repairs.
10. Plant, interest and depreciation.

11. Cost of trestles, falsework, bracing, forms and temporary supports.
12. Quarry rent, sand pit rent, timber stumpage, etc.
13. Cost of materials f. o. b. for a unit of the structure, including wastage.
14. Freight on materials.
15. Cost of unloading, hauling and storing of materials.
16. Cost of delivery and re-handling materials until at the place to be used.
17. Labor of handling, shaping and placing materials.
18. Foremen's salaries.
19. Salaries of watchmen, timekeepers, clerks, bookkeepers, etc.
20. Office and traveling expenses.
21. Interest on cash capital (plant not included).
22. Taxes, licenses and insurance of property.
23. Insurance of workmen and the public against accident.
24. Premium paid to bondsmen or surety company for bond required.
25. Advertising, legal expense, charity.
26. Discount on warrants, notes or other paper payments for work done.
27. Percentage added to materials and percentage added to labor, to cover contingencies.
28. Percentage added for profits.

Unbalanced Bids.—A bid is said to be unbalanced when too high a price is purposely bid upon one or more items, accompanied by an offsetting low price on one or more of the remaining items. Thus, if a fair bidding price for earth excavation is 25 cts. per cu. yd., and for rock, $1.00 per cu. yd., the following forms an example of a bid that is balanced, and one that is unbalanced:

Balanced Bid.

1,000 cu. yds. rock, at $1.00	$1,000
20,000 " " earth, at $0.25	5,000
Total	$6,000

Unbalanced Bid.

1,000 cu. yds. rock, at $2.00	$2,000
20,000 " " earth, at $0.20	4,000
Total	$6,000

It will be seen that the total bid, $6,000, is the same in both cases. In the second case, however, the $2 bid on rock is altogether too high, and the 20-ct. bid on earth is too low, hence the bid is unbalanced. The objects of unbalancing bids are three: (1) To secure an abnormally high profit on any item the yardage (or quantity) of which is likely to be increased after the contract has been awarded; (2) To secure a large profit on the items of work that must be done first, thus skimming the cream of the contract in the very beginning; (3) to conceal from engineers and from competitors what each item of work is actually worth.

To prevent the unbalancing of bids, engineers resort to various expedients, among which are the following: (1) Insertion of a clause in the "invitation to bidders" warning them that an unbalanced bid will cause the rejection of the bid; (2) requiring a lump-sum bid on the work; (3) publishing the engineer's schedule of items and an estimated price for each item, then requiring either (a) that each contractor shall bid a uniform percentage on all the items, or (b) that the contractor shall bid his own price on each item, no unit price being in excess of a certain percentage of the engineer's estimated unit price. The first of these two methods is called the "percentage method of bidding." I have discussed the advantages and disadvantages of each of these methods in the editorial columns of Engineering News (1903-1905).

A fourth method of preventing unbalancing of bids on small items likely to be increased in quantity may be suggested. It would consist in naming a definite unit price that will be paid on each of the minor items, and leaving the contractor free to bid his own prices on the other items.

The greatest danger from an unbalanced bid lies in subsequent change of quantities. Suppose that in the above given example, actual work discloses that a far greater quantity of rock exists than the 1,000 cu. yds. given in the bidding sheet. Suppose the actual quantities in the final estimate are reversed, and that there are 20,000 cu. yds. of rock and 1,000 cu. yds. of earth. We then have these results:

Balanced Bid.

20,000 cu. yds. rock, at $1.00	$20,000
1,000 " " earth at $0.25	250
Total	$20,250

Unbalanced Bid.

20,000 cu. yds. rock, at $2.00	$40,000
1,000 " " earth, at $0.20	200
Total	$40,200

We see that if the unbalanced bid is accepted the work costs in the end almost twice as much as it would have cost had the balanced bid been accepted; yet the two bids were the same ($6,000), according to the preliminary estimate.

It rarely happens that such an extreme case as this occurs in practice, although I have known several quite as bad. The principle, however, is best illustrated by an extreme example.

It is common practice among paving contractors in many cities to unbalance their bids for the sake of concealing their estimates of actual worth; as, for example, among asphalt paving companies. Bidding prices must, therefore, be looked upon with suspicion always, especially when used as guides for estimating.

An unbalanced bid is a two-edged sword. It may actually ruin the contractor that makes it, if it happens that he has erred and that the quantities on which he has bid too low are greatly increased, without a corresponding increase in the quantities on which he has bid high. Like all tricky practices, it is a dangerous one.

Causes of Underestimates.—Engineers have been said to be men who can be relied upon in every respect save one —ability to predict the cost of work. The reasons why engineers' estimates are so often unreliable may be enumerated as follows:

1. Students of engineering are seldom trained in the art of cost estimating, but left to acquire that art haphazard after graduation.

2. Articles descriptive of engineering structures seldom contain an analysis of the unit costs.

3. A subsurface survey is frequently not made; and, as a consequence, unexpected materials are encountered in excavating.

4. A study of the sources of local materials, their suitability for the work, and their unit cost delivered, is often not made; and, as a result, specifications are frequently

drawn that cannot be lived up to except by importing materials at great expense.

5. The cost of clearing, and draining the work is often underestimated, or ignored entirely.

6. The cost of temporary bracing, supports, roadways, and development expenses are frequently underestimated or omitted.

7. Delays due to bad weather, and delays incident to the shifting of plant from place to place are often not considered.

8. Interest and depreciation of plant, and the percentage for profits, are usually underestimated.

9. Inadequate allowance is made for superintendence and general expense.

10. The cost of inspection and engineering may be underestimated.

11. Legal expenses due to the abandonment of the work by a contractor, or due to suits brought by those who claim damages to life, limb or property, are generally not allowed for.

12. Changes in the alinement or in the design, made after contracts have been awarded, may result in large claims for extra compensation.

13. Omissions due to carelessness or ignorance of subordinates in the engineering staff may result in further claims for extras.

14. Rates of wages and prices of materials may rise; and, if the work is large, the work itself may be the cause of such increases.

15. When high wages are due to scarcity of men, an "independence" is bred in the workmen which decreases their efficiency.

16. A large number of competent foremen frequently can not be secured for extended work, resulting in decreased efficiency of workmen.

17. If an estimate is based upon previous contract prices there is grave danger of error, due to change in conditions, unbalanced bids, etc.

18. If unit prices are estimated before the specifications are drawn, the specification requirements may be made such as greatly to increase the cost of important items.

19. Limiting competition by the drawing of unfair, or indefinite specifications, is a common cause of high bidding

prices. Severe interpretation of indefinite clauses often causes failure of contracting firms, and the history of such failures operates to limit subsequent competition, and raise prices.

20. Contractors may combine, especially where the work is let in very large contracts, and raise prices.

Uniformity in Units of Measurement.—The economic importance of uniformity in units of measurement cannot be overestimated. To illustrate: The common unit of concrete work is the cubic yard, but it is customary to measure cement walks in square feet. Now this leads to many blunders, not only in estimating the cost of walks but in effecting reductions in cost. Not only does the thickness of cement walks vary widely, but the proportion of cement to sand in each layer of the walk is a variable. Therefore, to say that it takes so many barrels of cement to make 100 sq. ft. of walk means next to nothing unless the plans and specifications for the walk are also given. For purposes of accurate estimating it is necessary to prepare tables of cost of mortars and concretes in terms of the cubic yard; then by remembering that 100 sq. ft. having a thickness of 1 in. are almost exactly 0.3 cu. yd., it is a simple matter to convert costs per cubic yard into costs per square foot.

Not only in computing costs of cement walks, and the like, but in reducing costs, does it aid us to use the cubic yard as the unit; for it enables us to make comparisons, and thereby discover inefficiency of workers. Elsewhere in this book a case is cited where the labor cost of the face mortar for a concrete wall was out of all proportion to what it should have been. Had the contractor estimated the cost of this mortar in cubic yards, he would have discovered that it was excessive. The labor of mixing mortar should not be much greater than the labor of mixing concrete per cubic yard, nor should the labor of conveying the mortar in wheelbarrows be greater. The labor of placing it in a thin layer is obviously greater than for placing concrete in thick layers; but, in the case mentioned, the contractor was losing his money in mixing and conveying the mortar. He had not recognized the fact because he had not reduced its cost to dollars per cubic yard of mortar.

In like manner, one may often see money wasted in making and delivering mortar to bricklayers and masons, be-

cause the cost of the mortar itself in terms of the cubic yard of mortar—not of masonry—has not been calculated.

The cost of labor on forms and falsework should always be recorded in terms of 1,000 ft. B. M., as the unit; for that is the common unit of timber work, and, being so, ready comparisons can be made only in dollars per M. B. M.

It is surprising how few managers of men have realized the value of reducing the cost of each item of work to units that are comparable; and by this I mean units in terms of which entirely different classes of work may be compared. Thus, in a brick pavement there is grout used between the joints. This grout is a thin cement mortar, and it averages, let us say, 6 cts. per sq. ft. of pavement. Now, what does it average per cubic yard of grout? Probably not one paving contractor in a thousand knows; but until he does know he cannot compare the cost of grouting with the cost of other kinds of cement work. Many a time have I had my eyes opened to unsuspected losses and inefficiencies only by reducing the costs of the elements of work to units comparable with the units of similar work in other fields.

The ton is a very convenient unit to use when comparing the cost of loading and handling materials of all kinds. The ton of brick, the ton of gravel, the ton of timber, the ton of cast iron pipe, are loaded upon wagons by hand at a cost differing not so much, one from the other, as might at first be supposed. When reliable data are not available for estimating the cost of handling any given material, by reducing it to tons an approximate estimate can usually be made that will be satisfactory—at any rate far more reliable than a guess.

Subletting Work and Purchasing Materials,—There is seldom a contract that does not involve subcontracting. even when the original contract specially prohibits subcontracting. Every purchase of materials for which cash is not paid at once is a subcontract. The term subcontracting, however, is commonly applied to the awarding of a contract by the contractor; the subcontractor being one who undertakes to furnish the labor and materials necessary to perform a given portion of the original contract. Whether it be a purchase of materials or an award of a subcontract, there is one thing the contractor should never neglect to do, and that is to attach a copy of the original specifications to his letter or to his subcontract. In his let-

ter or his subcontract he should make definite reference to the attached specifications, stating that the materials, or the work, or both, must conform to those specifications. Failure to do this may lead to serious misunderstandings and loss. For example, in ordering paving bricks from a factory if the contractor fails to say that they must be subject to the inspection and tests of the engineer, and if a large percentage of the bricks are "culled" (rejected), the manufacturer may refuse to supply other bricks to replace the "culls."

Another point that should never be overlooked is to have a *written* contract (an exchange of letters will suffice) for any materials or work involving a sum in excess of the sum specified in the Statute of Frauds of the State in which the material is purchased. In some States this sum is less than $100 and in others it is $500. Any verbal contract, no matter how many witnesses may be brought, is voidable if the sum involved is in excess of that prescribed in the Statute of Frauds. It is startling to find how many contractors are ignorant of this law. Once the materials ordered under verbal contract have been delivered and accepted, the verbal contract as to price becomes binding.

It is poor practice, in my judgment, to buy or rent anything by word of mouth; and foremen should be required to make all purchases by written order, keeping a carbon copy. All renting of tools or plant should be recorded in writing, by an exchange of letters or otherwise, so as to have the terms of the rental signed by both parties. I have had the verbal rental of a plow by a foreman cost me $100 in lawyers' fees, etc.

A few suggestions regarding the subletting of work: Subletting should not be forbidden in the original contract. Repeated subletting of the same part of a job may be, and often is, pernicious in its effect upon the quality of the work. One subletting often results in lower cost of work, for a subcontractor who gives all his attention to a small job can usually get the workmen to do more work than a large contractor who has many things to attend to. The subcontractor is really a superintendent or foreman whose salary is paid in profits; and he has the best possible spur to secure the greatest possible economy.

The letting of several independent contracts for the different parts of a structure generally leads to delays and

claims for extras due to delays. One independent contractor may purposely delay another. All this is avoided by awarding the whole structure to one contractor, who can usually manage several subcontractors much better than several independent contractors can be managed by an engineer.

Contract vs. Day-Labor Work.—In spite of the fact that railway companies, mining companies and manufacturers have learned, through long experience, that it is cheaper to do work by contract than by day labor under their own superintendents, every little while some engineer thinks that he has discovered a better way of doing work than by contract. In my judgment the ideal system of doing every kind of work in the world is by contract. I include under contract work all piece-work, for in the case of piece-work the contract is with an individual who is paid at a specified rate per unit.

The reason for the economic effectiveness of contract work is this: The vast majority of men need more of a spur than the fear of discharge for incompetency. Foremen and superintendents are no exception to this rule. A contractor is a foreman or superintendent whose spur to activity and to the exercise of his brain is the knowledge that his salary is his profits, and that his profits depend upon his own efforts.

Occasionally a man may be found who needs no such spur —or thinks he doesn't—and he may handle work for his employers as cheaply as it can be done by contract. There are other men who, through ignorance as to the cost of plant maintenance and the hundred and one small items forming "general expenses," overestimate the profits on contract work, and honestly believe that their employers can do work more profitably by day labor.

When examples are cited to prove the economy of working by day labor, as compared with contract work, it is wise to ask for the written specifications under which the work was advertised and for the written specifications under which the work was actually done. An ambiguous specification will force careful contractors to bid high. That kind of a specification is usually interpreted in the most lenient manner by the engineer who drew it, if he himself does the work under it by day labor. No fair comparison

can be made between contractor's bids and costs by day labor under such conditions.

Political and social favoritism operates in the highest degree under the day-labor system of doing work. But no kind of favoritism, save that due to demonstrated efficiency, influences a contractor in selecting foremen or men—provided he is free from labor union tyranny.

There is one condition under which day-labor work may prove more economic than contract work. When it is impossible, without undue expense, to predict with accuracy the quality and quantity of each important item of work, then it often proves more economic to do the work by day labor, for bills of extras and law suits are thus avoided. Work that cannot be readily measured and inspected comes under this head. Thus, it is difficult to measure and inspect street-sweeping, railway track maintenance, and many other kinds of work, which are at present done best by day-labor. My belief is, however, that much of this class of work can be measured and inspected and predicted as to quantity and quality, provided brains are put into an effort to devise ways and means.

Contracting by the paying of the actual cost plus a percentage is one way of doing certain classes of work more economically than by day labor. The objection to this method is that it puts a premium on sloth.

A better plan is to pay the contractor the actual cost plus a fixed sum agreed upon in advance. This makes it no object to be lazy, for the contractor has a strong incentive to finish the work as rapidly as possible in order to be free to take another contract. For difficult work, for rush work, and especially for building construction, this plan of "cost plus a fixed sum" has some good features in its favor. Some architects' specifications are things "fearfully and wonderfully made," and their inspection of work is often worse than their specification—both leading to the scamping of work and to unreasonably large bills for extras. These are avoided under the "cost plus a fixed sum" contract.

Wherever piece-work can be done there is no need of a contractor (using the term in its commonly accepted sense), for every worker is then a contractor; but where piece-work is impracticable the most economic way, in the

long run, is to award contracts for all work that can be fully and clearly specified as to quantity and quality. Other work may often be cheaper "by the day."

Instructions to Superintendents and Foremen.—Some of the most successful contracting firms have sets of rules and instructions printed for the use of foremen and others. Certain of the "rules" are inflexible and must be obeyed; others are more in the nature of suggestions intended to guide the foreman in doing his work, handling his men, purchasing materials, and the like.

I will give a list of instructions that is by no means exhaustive, but varied enough to give some hints as to the character of a set of instructions. Rules such as these can be mimeographed on small sheets of paper and bound together with clips, so that they can be carried in the pocket for reference.

1. When a foreman arrives at a place where he is to have charge of work, he must notify the home office at once by postal card, giving the address of his boarding place and his office address.

2. A daily report must be sent to the home office on the blanks provided. If no work is being done, still a report must be sent in stating that fact, and giving reasons for delays, etc.

3. Each foreman must keep a small diary in which to jot down the principal events of the day. Such a diary may be of great value in case of a law suit.

4. Each foreman must write all orders for materials, supplies, etc., in the book provided for the purpose, so that a carbon copy of every order will be kept. He must be careful to insert the day of the month. When a foreman wishes grading stakes, or instructions from engineers in charge of work, let him send a written order to the engineer stating exactly what is wanted. This precaution may save misunderstandings and delays, and the carbon copy of such an order is often useful to check the memory. The sooner a foreman learns to be methodical in such small matters, the sooner will he be fitted to handle larger matters.

5. No superintendent, walking-boss, engineer, timekeeper, or other employee of this firm, is permitted to give an order direct to any workman, except in case of great emergency. Not even a member of this firm is exempt

from this rule. The foreman in direct charge of a gang of men is the only man permitted to instruct his men what to do. He is the officer in charge, and his superior officers must not intentionally or unintentionally degrade him in the eyes of his men, by issuing orders over his head.

6. A foreman is not permitted to work with his men. He is employed to use his wits, not his hands. Occasionally he must instruct a man how to do his work, but he must teach the man and not attempt to take the man's place. It may take a foreman longer to teach a man than to do it himself; nevertheless it is cheaper in the long run to teach the man.

7. Do not use laborers to do the work of masons or carpenters, but provide a sufficient number of laborers to assist the skilled workmen. A 15-ct. man can lift as many pounds of wood or stone as a 50-ct. man. Exercise your wits in keeping each class of men busy at their particular class of work.

8. In rainy weather keep all steady-pay men busy overhauling machines and tools, sharpening tools, branding tools, splicing ropes, etc.

9. Rush all percentage or force-account work exactly as if it were part of the regular contract. The reputation of this firm is worth more money than can ever be made by "making work last."

10. Small jobs of extra work are usually taken on a basis of 20% profit on both materials and labor. This leaves but a small margin of profit after deducting general expenses. It is particularly desirable to work as many men as possible on a small job, so as to reduce the percentage of general expenses.

11. Keep the addresses of good workmen.

12. Do not be a "good fellow" with the men under you after working hours, or you will lose their respect. Remember the old adage, "Familiarity breeds contempt."

13. In case of any accident to a workman or to a spectator, notify the home office at once by letter. If the accident is fatal, notify by telegraph or telephone. We are insured against such accidents, but by the terms of our policy we must notify the insurance company within 24 hrs

14. The best and cheapest insurance against accidents is care. Provide barricades, warning notices and red lights wherever an excavation is made. Even a small hole un-

protected may cause the loss of a life, for which the courts may hold this firm responsible. When a street is closed by barricades, do not permit an outsider to enter even at his own risk; for should an accident occur a law suit is certain to follow regardless of the rights involved.

15. Accept no orders for extra work except in writing, and forward such orders at once to the home office.

16. Fill in your expense account blank every Saturday night and send to the home office.

17. When plans are received indorse your name upon them, with the day of the month and year. Write on blueprints with a red pencil.

18. Avoid all controversy with an engineer or inspector. A small quarrel often leads to a big loss. Notify the home office in case of unfair or unreasonable orders.

19. When a car arrives, record its number and character of contents. Remember that a demurrage is charged on all car-freight held more than 72 hours; but on most roads demurrage is estimated by averaging. Thus, if one car is held 24 hours before unloading, and another is held 96 hours; the average is $(24 + 96) \div 2$, or 60 hours.

20. Pile lumber with the boards slanting so that water will drain off. Lay as few boards or timbers directly on the ground as possible. See that the top layer of boards is turned over occasionally to prevent warping.

21. Insure all lumber and timberwork against fire.

22. Count and measure all sticks of timber to check the bill. To calculate the number of feet board measure (ft B. M.) in a sawed stick of timber, multiply the width in inches by the thickness in inches, divide this product by 12, and multiply the quotient by the length of the stick in feet.

23. See that all shipments of materials are counted or measured, and recorded.

24. For convenience in estimating the weight of materials remember the following:

Material.	Cu. ft. per ton of 2,000 lbs.
Water (62½ lbs. per cu. ft.)	32
Sand or gravel	20
Broken sandstone, limestone or granite	22
Broken trap-rock	20
Solid blocks of granite	12
Coal, broken	40

Green white oak is heavier than water, and weighs more than 5 lbs. per ft. B. M. (there being 12 ft. B. M. per cu. ft.) Green southern yellow pine weighs 4½ lbs. per ft. B. M. Kiln dried oak weighs 3¾ lbs. per ft. B. M.; and kiln dried yellow pine weighs 3 lbs. per ft. B. M. In any case, by floating a block of wood in water and measuring the total depth of the block and the submerged depth, the weight can be calculated by simple proportion, thus:

Depth of block submerged: Total depth of block :: The weight per ft. B. M.: 5.2. Thus if the block is 6 ins. deep, and 4 ins. are submerged when it floats, we have:

$4 : 6 :: x : 5.2.$

Whence we find that x is nearly 3½ lbs. per ft. B. M.

Familiarize yourself with other rules useful in computing weights, etc.

25. On short hauls where dump wagons are not available provide extra wagons which can be loaded while the full wagons are going to the dump and returning. Extra wagons can usually be rented, and in some cases it will pay to buy them, for the lost team time soon eats up the price of a wagon. Extra wagons are especially useful where a small gang of men is unloading brick, stone or timber from a car onto the wagon. When a team comes up with an empty wagon, unhitch from the empty, hitch to the full wagon, and with a tail rope pull the empty wagon up to place as the full wagon moves ahead.

26. In erecting a derrick or pile driver remember that a gin-pole or mast can often be used to advantage. Gin-poles are not used as often as they should be for this kind of work.

27. In erecting a trestle for falsework, frame and bolt the bents together on the ground, then up-end them.

28. Use round timber for legs of temporary trestles, for trench braces, and wherever struts are needed. Round timber can usually be bought for much less money than sawed stuff.

29. In buying brick consider the size of each brick; bricks vary greatly in size. Large bricks are worth more per M than small ones. If 2 × 4 × 8-in. bricks are worth $6.50 per M, every ⅛-in. increase in the length adds 10 cts. per M to the value; and every increase of ⅛-in. in thickness adds 25 cts. per M.

30. In buying cement, consider the size of the barrel, and the amount of cement paste that can be made with a barrel. There is a great variation in the product of different factories.

31. Buy cement in wooden barrels for use on small jobs that are liable to lag. Buy cement in cloth bags for most work. Pack the bags in bundles of 50, and ship to factory. Cement improves with age up to a certain point, if the air is not too damp. Use the oldest cement first.

32. Dynamite must never be thawed in any way except with a hot water thawer of the kind furnished by this firm. Never thaw in front of a fire, or on a hot stone removed from a fire, or by piling sticks on a boiler, or in an oven. We know of fatal accidents due to each of these methods. There may be safe methods other than the one above ordered, but we can not afford to experiment where lives are at stake.

33. Never store dynamite, or acid, or gasoline in a tool box. The dynamite may be exploded; the acid vapors will eat into ropes and rot them; the gasoline vapors may explode or spilled gasoline may result in a fire. Use sand to put out a gasoline fire. Hemp rope is weakened not only by acid vapors, but by saturation with oil. All rope should be kept dry.

34. In using steam engines, steam drills and derricks, the following precautions should be observed:

Daub grease over all bright parts before storing, also in wet weather. Oil the derricks, crushers, wire ropes, and all movable parts of machines every day. Cheap black grease is usually daubed on wire ropes; but where the ropes are moving over sheaves almost continuously, provide an oil drip cup to feed oil, drop by drop, onto the moving rope.

Do not permit men to wash their hands in the water barrel or tank that supplies water to a steam boiler, for the grease from their hands will cause "priming."

Boiler flues are frequently "burned" because water is allowed to get too low in the boiler. Aside from the danger of a boiler explosion in such cases, there is the certain cost of repairs. See that the steam cocks are blown off several times daily; and do not rely upon the water glass.

A lazy or ignorant fireman will pile on coal, and then rest until it has burned low. See to it that a thin bed of fuel is kept steadily burning. On large boilers use an

automatic pressure recording gage to make the firemen attend to their business properly. It will not only save coal, but result in greater output of engines and steam drills.

Cylinders of engines and steam drills are frequently cracked in cold weather by suddenly letting in steam. To avoid this open drip cocks and cocks on steam chest and blow in steam for a few minutes to warm up the cylinder before starting the machine. A broken cylinder may delay work for a week.

Do not let a friction clutch get wet, for it may slip if it does.

Lower the boom of each derrick at night, so that it can not be dropped by some one for fun or for spite. Lay down short logs at intervals to keep the hoisting rope clear of the ground.

The foregoing will serve as examples of instructions to foremen. Each contracting firm will have certain classes of work in which it specializes, and will find it advisable to prepare mimeographed or printed instructions not only of a general nature but of a special nature. Thus, a firm engaged in building construction may give sketches of scaffolding and instructions as to its erection. A firm engaged in bridge building may prepare a set of rules to guide the foremen in coffer-damming and in false-work building.

System is fast taking the place of the hit-or-miss style of directing work. A well prepared set of instructions to foremen is an essential part of any complete system of management.

SOME HINTS FOR YOUNG CONTRACTORS.*

PART I.

Advice to beginners in professional work or in business is commonly supposed to fall upon dull ears, still the writer well remembers the subsequent value of certain suggestions once given by a experienced contractor, and is inclined to believe that not all advice is wasted even upon the most

*These "Hints" were originally written by the author as a series of editorial articles in the Construction News Supplement of Engineering News, May 12 to June 16, 1904.

self-sufficient young man. Not a year passes but a score or more of special lectures are given to students of engineering by old graduates who offer many suggestions to the young men about to enter upon their professional practice; but, for obvious reasons, we look in vain for similar advice to young men intending to become the actual builders of engineering structures. The absence of courses of instruction in the business of construction and the fact that no society of contractors for engineering works exists, account in large measure for the dearth of information that might save many a young man from failure in his first attempts at contracting. To the experienced contractor much that follows will seem too self-evident to merit reading, and with some statements he may not agree. At any rate the advice and suggestions will possess the merit of being founded upon personal experience, observation and conversation with contractors, and as such, may waken thought even if the suggestions themselves are ignored.

It is not likely that any young man will begin contracting until after he has been for some time either an employee of a contracting firm or an engineer in charge of contracting work; but it is quite common for a young man to undertake contract work on his own responsibility after a short experience on one class of work only. If this work has been work involving few risks, such as brick paving, for example, the young man may succeed from the start; but if the work involves more expense for labor than for materials, the tables are apt to be turned. The first consideration, therefore, should be the proportionate cost of labor and materials. Quotations can be secured from manufacturers and transportation companies that will enable the contractor to estimate with great accuracy what his materials will cost delivered; but the cost of the labor factor will depend upon himself, upon his foremen, and upon the quality of the laborers—all more or less indeterminate factors. The logical conclusion, but a conclusion seldom formulated in words, is:

A small per cent. may be added for profit on materials, but a large per cent. should be added for profit on labor.

Under no consideration should the young contractor "lump together" all items of cost and add a fixed percentage

for profit. Let him segregate the material items, whose cost he can ascertain with accuracy, from the labor items. Add, say, 10 to 20% to the cost of materials for profit in furnishing and handling them; but add at least twice as large a percentage to the estimated cost of labor and superintendence. A good general rule to follow is 15% for profit on materials and 30% on labor and superintendence—not forgetting the superintendence. Text books written by civil engineers who have had no experience as contractors very often contain statements to the effect that "the proper allowance will usually be 5 to 15%." This quotation is from a paragraph referring to the cost of earthwork! Of course the contractor will figure on low profits where the work is of considerable magnitude, and when he is practically certain of a probable labor cost by virtue of previous experience under precisely the same conditions; but we are speaking now of small jobs such as the young contractor is likely to undertake at first.

This leads us to a consideration of the magnitude of the work that a young man may safely undertake to perform. With all the capital to be desired for large undertakings at hand, still would the young contractor be exceedingly foolish to bid upon one very large job, or a large number of smaller ones at one time, until he has successfully finished a few smaller pieces of work. The reasons for this are not always apparent to the young man, particularly if he has a bold rather than a cautious disposition. He has friends or relatives who may be willing to put money into a business venture, and he is flattered by their trust in him, and by his own previous success as an employee. He has read or heard of the startling successes of young men in business, and, having no knowledge of the innumerable failures, he is eager to plunge in where the biggest whales swim. Indeed, were he told of all the failures of young men who have been too bold, still would he count himself the exception, and give little heed to advice—unless that advice were backed by reasons. We purpose, therefore, giving a few reasons why the young contractor should work up gradually, taking successively larger contracts as his experience grows.

In the first place it is evident that the larger the contract the more numerous the foremen and bosses. Where are fore-

men to be found, if a large contract is awarded to you? Can you enumerate even five good foremen upon whom you can lay your hands to-morrow? You are to be the general, but who are to be your captains and your lieutenants? Do you fancy that you can pick them all up by advertising and accepting each man at his own estimate? If so, a woeful disappointment is in store. The best foremen are already in the employ of your competitors. You can get similar men only by a painfully slow weeding out process. This fact, so often overlooked, is indeed the cause of innumerable business failures in all lines of commercial work—the laziness or inability of subordinate managers.

If the job is a small one where you can be your own foreman at first, you will eventually be able to pick out and educate one good foreman after having tried half a dozen; and this experience will teach you not only the scarcity of men able to handle men, but it will be an invaluable training in the art of handling men—an art that even when inborn requires cultivation by long practice, precisely as does any other art. The contractor who cannot manage a gang of common laborers is quite certain to be unable to manage his foremen. It requires the same severity of discipline, the same show of harsh exterior, the same proneness to find fault rather than to praise, in order to spur foremen to action as it does to spur the laborers under them to action.

There is another reason why a man of slight experience should not undertake to manage a large piece of contract work, even if he were provided with the best of foremen. The better the foremen the more quickly will they discover any weakness or lack of knowledge on the part of the contractor, and they will be more than human if they do not take advantage of this weakness. Even if they do not contrive directly in some way, to "make the job last," they will surely add materially to the cost of the work in one way or another; for it is human nature to take advantage of every weakness that may be discovered in a superior officer. The general must inspire confidence in his strength of character, largely by his knowledge of details and his insistence upon the prompt and proper attention to every detail. An inexperienced contractor may, for example, be quite hazy as to the proper handling of timber-work, whether for temporary

or permanent structures; his boss carpenter, will, in all probability, know that pneumatic boring machines should be used, but, if not provided with them, will make no requisition for them. The man who has come up from the ranks seldom has any friendly feelings for labor-saving devices, and this feeling clings to him even after he has become a foreman. It requires, as a rule, an intimate and personal contact with workers in the different trades to learn such facts as these, and one does not get personal contact by acting as a time-keeper or as an engineer setting stakes and computing quantities.

This leads us naturally to a brief consideration of the subject of labor-saving devices—that is of the plant needed to perform any given class of work. With plant as with foremen, a weeding out process secures the best, and such a process cannot be made the work of a few days. The technical papers do not give much information in their columns that will be of assistance in selecting machinery and tools, and text books give less. Consulting engineers might often give valuable advice, but strangely enough the man who would not draw up a $500 lease without consulting a lawyer, will buy a $5,000 machine without consulting anybody. Indeed, he may not even take the pains to visit contract work in his own county to learn something from the experience of others. Perhaps the most valuable piece of advice to a young contractor is this: Whenever you are at liberty, spend some of your time visiting and studying the machinery in use on contract work.

The longer a contractor has been in business the more cautious does he become in selecting machinery. Not always is the most widely advertised tool the best, although it is pretty safe to assume that the successful manufacturer advertises liberally, and if he has been in business many years his machines must be giving satisfaction. The well-established and experienced contractor can afford to experiment with newly invented machinery, but the beginner in contracting never should. He will have his hands full organizing and handling the work without attending to the development of some new labor-saving device; and in this connection it may be well to add that no matter how promising the labor-saving device may appear, the bidding prices

should not be made a whit lower than they would be with older types of machines.

The subject of machinery and plant is one upon which it is difficult to be brief, but one more hint must suffice. Civil engineers are prone to underestimate the percentage that should be allowed for interest and depreciation, and this holds true of every one who has not had to "foot the bills." We often see absurdly low estimates of the cost of dredging in which either no allowancce at all is made for "plant rental," or the allowance is so low as to expose the ignorance of the writer upon matters pertaining to cost.

Bear in mind that a contractor's plant is generally idle much of every year, and that one or more years may pass without its doing any work at all. The Massachusetts Highway Commission, for example, reports that the steam road rollers owned by the State average about 100 days worked out of the 365 in the year. This agrees with the writer's estimate made some years ago. Perhaps as good a way as any to determine roughly what amount should be charged for plant interest and depreciation, is to secure quotations from those having plants to rent. The quotations will always seem exorbitant to the inexperienced contractor, but he can rest assured that he will find in the long run that no great profit is made by those who rent contractors' plants. Indeed one of the best pieces of advice that the writer recalls having received from an experienced contractor was put very much in the following words:

"Don't be in a hurry to own your plant. Rent one for a while until you learn something about it. Perhaps you may not like that kind of a plant at all, after a few weeks' use. Perhaps you may get sick of the kind of contracting requiring the use of such a plant. In either case you are out of pocket only a little money at a time, and not a big sum at once; and, if you have made a rental contract that entitles you to lower rates the longer you keep the plant, you will in the end have paid out considerably less than the cost of a new plant, and have, in consequence, more working capital with which to undertake the next job. It's cash that counts; for you can't mortgage a lot of derricks and engines for enough money to pay freight on them to the next job."

In the foregoing paragraph there is one statement that

deserves emphasis; and that relates to signing a contract for plant rental. Usually no formal contract is signed, but the agreement is made by letter. If the rental rate is by the day, be careful to define what constitutes a day, and whether Sundays, holidays and days not worked are included. But the most important thing to bear in mind in renting a plant is to secure a sliding scale rate, depending upon the length of time the plant is used; so and so much for the first month, a lower rate for the second month, and so on until a minimum rate is named for each month after a certain date. Do not make the common mistake of assuming that your use for the plant will have ceased before the expiration of the time limit of your contract. There may be extra work; there may be delays in securing materials; there may be storms; there may be strikes; and, finally, there may be errors in your own estimate of the time required to perform the work in hand. All these are reasons why a sliding scale agreement should be made.

PART II.

The crucial test of a contractor's fitness for his work is the ability to handle men, but second only in importance is his ability to estimate the probable cost of work. These two qualifications are not often combined in one man and, as a rule, the most successful contracting firms contain one man whose special aptitude is organizing and handling men, and another whose training and natural bent fit him to estimate costs, to keep records and to act in advisory capacity on all matters pertaining to the selection and use of machines and tools. An experienced foreman and a young civil engineer often make an excellent contracting firm, the one possessing a knowledge of men and methods, the other a knowledge of costs. We do not mean to imply that the young engineer is apt to know much about costs at first, but that his training has been such as to fit him to keep systematic records and to analyze costs. Such firms often break up because each man overestimates his own worth and underestimates the worth of his partner; but the longer they work together, after the second or third contract has been finished, the less egotistic is each man apt to become and the more wideawake to the true worth of his associate in business.

In order to fix a bidding price on the proposed work, if no actual records of similar work are available, it is customary to hunt up bidding prices on similar work, strike an average, bid a little below the average—and trust to luck. To make this process less of a gamble, it is wise to secure back volumes of engineering periodicals, and make a scrap book using the pages of the journal that relate to contract prices. Then as the scrap book should be indexed, a word as to indexing may be of assistance. There should be heads corresponding to the items usually found in bidding sheets, as follows: Asphalt Pavement, Ballast, Bolts and Spikes, Brick Masonry, Brick Sewers, Brick Paving, Bridges, Castings, Catch-basins, Cement, Clearing and Grubbing, Concrete, Curbs, Earth Excavation, Embankment, Flagging, Flush-tanks, Gravel, Gutter, Hydrants, Iron, Lampposts, Lead, Macadam, Manholes, Masonry (stone only, and not brick or concrete), Piles, Pipe Sewers, Puddle, Railing, Riprap, Rock Excavation, Sidewalks, Sodding, Specials, Steel, Stone, Timber, Tracklaying, Valves, Water Pipe, etc. As far as possible select headings that denote the kind of material used in the structure; but where this cannot be done without confusion select the name of the structure as it ordinarily appears in bidding sheets. Do not, as a rule, use such headings as the following: Abutments, Filling, Dredged Material, Foundation, Vitrified Brick Paving, etc. An abutment often contains piling, concrete and cut stone masonry, and in using the index it may not occur to you to look under abutment when looking up prices on concrete.

Having decided upon headings, cut up a lot of paper strips about an inch wide and four inches long, and proceed to go through the printed pages to be indexed. When a bid on Concrete is found, write on one of these slips, "Concrete, pavement foundation, p. 80." Throw the slips aside as the index entries are made; and, after a volume has been indexed, assort the slips alphabetically, and have a typewritten index copied from them. Simple as this method is, the inexperienced man is not likely to think of it, and failing to think of it he will look upon the job of indexing as being so great a task that in all probability no index will be made. Indexes published at the end of the year by the technical journals are, as a rule, of no value to the contrac-

tor; furthermore, the current issues of construction news should be indexed as fast as received. Especial care should be taken to index classes of work that are out of the ordinary, for whenever bids must be submitted on similar work no better guide than previous contract prices is apt to be found.

The errors that are likely to occur by trusting to previously published contract prices have been discussed before, so that the subject need not be considered further.

If the amount of the work to be done is sufficient to warrant the payment of a small fee for advice, a consulting engineer, known to have had experience in work of similar character, may be called upon with advantage. The self-sufficiency of young contractors is often the cause of heavy losses which might have been entirely avoided by consulting an engineer. Engineers, it is true, are not always to be relied upon for close estimates of cost; the most common error being too low an estimate, due to a failure to add in the cost of development work, installing plant, plant depreciation, etc. But, on the other hand, the bids submitted by beginners in contracting are often so wide of the actual cost that no consulting engineer could do worse and few would be likely to err as badly.

The estimate of cost made by the engineer who drew the specifications should always be asked for, but frequently it cannot be obtained. If that engineer has had much experience in precisely the same class of work as the class specified, and in the same part of the country, his estimate of cost is likely to be reliable—otherwise not. Indeed, some of the most serious blunders are made by young contractors who put too much faith in estimates of cost made by the authors of specifications.

Finally, having secured all the bidding prices and estimates of cost that can be secured from outside sources, the contractor should proceed to make his own estimate of actual cost, separating each class of work into its minutest details. First, he should make a careful estimate of the probable cost of the necessary plant, for here it is that most beginners "fall down." There is a time-limit set upon the work. How much and what plant is needed to finish the work within the time-limit? If the work involves rock excavation, for ex-

ample, divide the total yardage to be excavated by the total number of days that will be available, after making a liberal deduction for time lost due to storms, etc. Then knowing the daily yardage that must be moved, ask yourself how many steam drills will be needed to break down that yardage daily. Next estimate the number of daily trips that can be made by the transporting machinery, whether it be cars, cableways, derricks, or what not, and determine roughly the amount of machinery required for transporting materials. In the same manner estimate in detail the amount of every class of machinery required—estimating liberally. Finally add 20% to the estimate to allow for machinery "out of business" in the repair shop, etc. Consider all hemp ropes, picks, shovels, and all small tools generally, as part of the development expenses and therefore worth nothing at the end of even a short job. An allowance of from 1 to 2% per month for depreciation of large machines, horses, wagons, etc., may be made; but much more should be allowed for depreciation and interest where the number of years that the plant will be in actual service is uncertain.

Having distributed the interest and depreciation charges over the yardage of materials to be handled, the cost of development work should next be estimated. By development work is meant the cost of building roads over which to carry machines and supplies, the cost of freight and haulage of plant both ways, the cost of erecting and installing the plant, the cost of temporary houses for men and teams, and, in a word, all preliminary work that must be done by the contractor without direct pay from any one. This development work is often a surprisingly large percentage of the total cost, yet it is an item commonly overlooked.

Having distributed the development work over the yardage of materials to be handled, the next item to consider is the cost of materials f. o. b. cars at destination, to which must be added the cost of loading, hauling, storing and rehandling at the site of the work.

Especial care should be taken not to omit the cost of falsework, forms, bracing and sheeting, cofferdams, and in fact all materials that do not appear on the bidding sheet. The same remark holds true of the labor of erecting and removing these temporary structures, as well as the labor and

power required for bailing and draining, night watchmen, and other labor items involved in protecting the plant and the work during construction.

Next in order of consideration is the probable cost of the various labor items involved in building the structure for which itemized bids are to be submitted. Having estimated the daily amount of work that each kind of laborer can be counted on to perform, do not fail to ask yourself whether one part of the work may not go ahead faster than another part, and thus keep some of the men idle part of the time. To illustrate, suppose that a derrick is serving two masons, with an engineer, tagmen, mort men, etc., in the gang. The derrick-engine and engineer may be capable of delivering 100 cu. yds. of stone in a day to the masons, but in practice only a small fraction of this 100 cu. yds. can be laid in a day by the men on the wall. In all cases consider carefully the limiting number of men who can be worked advantageously at any one place, and then ask yourself whether this limited number does or does not limit the output of other men and machines serving them.

Another point to consider in this connection is the lost time that occurs at regular intervals when machines and men must be shifted forward to new work. A steam shovel may be idle two weeks, for example, while moving it from one hill to the next. The masons and their gang may be idle, so far as productive work is concerned, while shifting the derrick along the wall.

Having estimated the average prospective output of each laborer, consider next the amount of supervision that will be required. On work that can be easily measured up each day, like slope wall masonry, one foreman can look after many men scattered over a large area; but in grubbing and clearing, each small gang requires its foreman; hence it is that the percentage of the total cost chargeable to supervision may be as low as 5% or as high as 20%. The contractor who has been working in a small way as his own foreman is apt to overlook this important item of supervision in estimating the actual cost of work. Each class of work, however, should be considered by itself, an intelligent effort being made to predict the number of men that can be worked under one boss.

The next item to consider is supplies. Supplies include explosives, fuel, water for boilers, lubricants, and a hundred and one small things seldom thought of by the inexperienced man. The two important items, explosives and fuel, should be estimated with care, and the others can be provided for in a general way by a liberal allowance for profit.

The last important item is General Expenses. This includes salary of general superintendent, salaries of office men, time keepers, traveling expenses, office rental, entertainment expenses, and the like. General Expenses will seldom run under 4% of the total cost, and they may easily be two or three times 4% on small contracts, or where there are long periods of idleness between successive contracts. Certainly no contractor can afford to ignore consideration of this item if he wishes to arrive at an exact cost of each item of work with any degree of accuracy.

PART III.

To know approximately what the actual cost of every item of work will be, is evidently the first consideration in making out a bid; but the second consideration is to bid so as to secure the greatest possible profit. To do this is purely a matter of business, involving no more of "trickiness" than every man in every trade exercises. The farmer puts up the price on wheat when wheat is scarce; the laborer demands higher wages when men are hard to get; and in turn the contractor bids higher when competition is light. An excellent plan in bidding is, therefore, to attend in person every letting so as to determine upon the prices to bid after noting the number of other contractors present. If a contract is worth bidding upon at all it is worth "going after" in person and not by letter. Moreover, when the bids are opened it is usually possible to secure the bidding prices of competitors; indeed, it can always be done on public works contracts. If the unit prices are read aloud by a clerk, the reading is usually so rapid that unless a blank has been prepared beforehand it will be found impossible to record the prices as fast as read. To prepare a blank, simply make a copy of the bidding sheet, leaving a sufficient number of columns in which to enter the bids of competi-

tors. By doing this beforehand no time will be lost in writing the names of items while the clerk is reading, and thus it will be possible to secure a complete record of every bid which should be subsequently entered in an office note book for future use in "sizing up" the probable bids of competitors.

Should it happen for any reason that the bidding prices are not given out, do not become confidential and disclose your own prices to some newly-met competitor. Quite likely he will agree to exchange price for price, and later on you may find, after all the bids have been rejected, that your friendly competitor had used your prices by which to gage his own subsequent bid, and has deceived you as to his own prices.

Returning to the subject of deciding upon bidding prices, make it a practice always to check the quantities given in the bidding sheet as far as possible. If the contract is a large one, or the work is such that you can not personally do all the checking, employ an engineer to do so. It is astonishing to note the number of errors, typographically or otherwise made, that creep into quantity sheets. An error of transposition is not uncommon; thus, the engineer may have correctly determined that there are 3,000 cu. yds. of embankment and 1,200 cu. yds. of riprap, but in the bidding sheet the quantities may be transposed so as to read, 1,200 cu. yds. of embankment and 3,000 cu. yds. of riprap. In looking over the quantities, therefore, always ask yourself whether each quantity "looks about right," or not. A shrewd contractor will thus discover errors that a whole staff of engineers have overlooked. Whenever you see a small, and what appears to be an arbitrary quantity, like 10 cu. yds. of concrete or 50 cu. yds. of rock excavation, look carefully over the plans and specifications to discover if possible where this quantity is shown in detail. If it cannot be found that the quantity has been actually measured, it is safe to assume that it has been guessed at, and that in consequence it may subsequently prove to be an underestimate. Bid liberally on such items, but bid not too liberally. More contractors, otherwise shrewd, make the error of bidding unreasonably high on such small items than one would expect to see. The result sometimes is that their

bids are rejected because they are "unbalanced;" or, if accepted, and later it is found that a larger quantity of the unbalanced item exists, the engineers may either change the plans or relet the work covering that item. Set it down that seldom is it good business policy to bid an unreasonably high price on any item even on public works contracts, and it never is wise to do so on private contracts. Even though the item is small, and the cost of putting up a plant to perform the work is large, still bid only a little higher price on the item than you would bid if it were many times larger, and distribute the estimated cost of plant over the other items.

Another point about bidding on public works is to bid high on the work let in the early part of the season so as to permit your competitors to "load up" with work in which the profits are small. Gradually you will find the prices rising as the season advances, and this holds true, whether the number of competitors is as great as ever or not; for, if there is a normal amount of work in sight, as each contracting firm secures what it considers its share, the firm will bid higher, if they bid at all, on subsequent work. The reasons for this are several. In the first place there is a limit to the plant investment that any firm cares to make, unless it is assured of large enough profits to offset the first cost of the additional plant. In the second place the greater the amount of work that any firm has on hand, above its normal amount, the more inefficient the laborers become; for the supply of reliable foremen that any firm can lay its hands upon is limited. In the third place, the banks are not easily induced to advance cash beyond a certain limit to any contractor. There are other reasons, but these are enough to show why, in the long run, it may be counted upon with certainty that a firm already "loaded up" with work will bid higher.

Of course, in hard times conditions are apt to be reversed, the eagerness to get work at any price becoming greater as the amount of the season's work becomes less. The law of supply and demand is one that business men should constantly consider; and we do not mean by the word "consider" that the existing supply and demand is to be looked into, but that the conditions of the future should be ex-

amined. It is not a difficult matter for a contractor to ascertain with some degree of accuracy, about how much money will be expended in any given locality on any given class of work, during the year. The appropriations made by legislatures and councils should be recorded and compared with those of previous years. The projected work of railways can usually be predicted with some accuracy after a few conversations with the "right men"—and it is a part of the farseeing contractor's business to know who are the "right men," and to keep in touch with them.

Whatever may be the line of work, a contractor should strive to foresee the business conditions of the coming year. In more ways than one this effort will ultimately be rewarded. If the work to be done involves extensive purchases of timber, brick, cement, or the like, then market prices of previous years should be platted on cross-section paper so as to show at a glance the monthly rise and fall for at least a decade past. Then if you are about to bid upon a contract which will run over into the next year, observe what the trend of prices has been and bid accordingly. Every wave has its crest as well as its trough—don't let yourself be caught bidding with trough prices.

Freight rates, and particularly rates of transportation by water, are subject to fluctuations that should be made a study by any one who is expecting to pay considerable sums for moving materials from one place to another. The writer remembers bidding on work involving the transportation of stone by canal. When the estimate of cost was made, the freight rate was 50 cts. a ton; but two months later it had risen to 75 cts., and ultimately reached $1 a ton before all the stone was delivered. Still some engineers wonder why contractors are not satisfied to estimate on a basis of 10 or 15% profit, forgetting that at best there is uncertainty enough in most cases to make foolish such close bidding.

Thus far we have discussed estimating costs and preparing bids; doubtless, however, some readers would like to know how an opportunity to bid can be secured. It is well known that railways seldom call publicly for sealed bids, but prefer to invite a few firms, well known to them to submit bids, and in some instances they even offer

work to a selected contractor at prices determined by the railway engineers. On the other hand, although any one may bid upon public works, it is not always possible to secure an award to the lowest bidder; or, if an award is made, political pull may be necessary to secure a profit. Under these conditions the young man is apt to lose heart, and conclude that the doors are closed and pretty well locked against him. But there is a way, of course, to push oneself into any business—and perhaps it is just as well that bugaboos stand at the gates to frighten away the timid.

To secure work from a railroad company one must be known; to be known one must have worked for the company—which has a sound like the injunction against going near the water until the natatorial art has been mastered. In fact, however, the steps necessary to make one's ability known to railway officials are simply the steps that any apprentice in trade must take. After a sufficient experience as timekeeper and foreman for a railroad contractor, an opportunity will eventually come to undertake a subcontract. This subcontract will be a small affair; but, for all that, the very best energies should be put into it, for it is a test case. Rapidity of execution is the secret of success in railroad contracting—or, indeed, in any class of contracting. Push it and keep on pushing it till the final estimate. To follow this injunction it is necessary to take a less amount of work than you feel yourself able to handle by personal supervision. Stand over it and sleep upon it, avoiding above all things the idea that now you are your own boss you are in the leisure class. In fact you may say, like Paul Jones, replying to the British admiral, "I have just begun to fight." For contract work is a fight and it takes fighting blood to win.

PART IV.

There is no class of contract work so easy to get into, and yet so hard to get out of with profit as a public works contract. In spite of the fact that the impression prevails that a political "pull" is necessary in order to secure a public works contract, there is little basis for this belief. Government contract letting is singularly free from unfairness,

although the scarcity of bidders often lends color to an opposite opinion. The reason for a scarcity of bidders on large contracts can usually be found in the specifications. Specifications so drawn as to put the contractor entirely under the thumb of the engineer by virtue of the ambiguity of the clauses, specifications that put all the burden of uncertainty upon the contractor's shoulders, specifications that, in a word, do not specify, drive cautious business men out of the bidding. Under this class come many of the specifications for large government contracts.

In the same class, also, are many specifications for city work—particularly sewer work. Rarely does a city engineer show a subsurface profile of the rock to be encountered; and quicksand is never shown. As a rule, the contractor is required to take all chances as to the character of the material to be excavated. This operates, of course, in the interest of a few local contractors (if it operates in the interest of anybody), and lends color to the cry of favoritism, although in fact the engineer is usually a fair man. In his desire to avoid claims for "extras," which have become a sort of bugaboo both to engineers and taxpayers, the city engineer has evolved a method of throwing the burden of all uncertainty upon the contractor by requiring him to name a price per linear foot of completed sewer, regardless of materials to be excavated. In a less degree, contracts for pavements have elements of uncertainty that tend to keep out bidders from other cities, the maintenance clause being the main element of uncertainty. If the clause itself is not indefinite, the probable traffic that will come upon the pavement is. In any case, few business men care to have all their profits tied up for a term of years, and rather than do so, they will either bid high or not at all.

Thus we see that political "pull" is by no means the all important factor in limiting competition for public work. It is true that in a few of our larger cities—to their disgrace—there is good reason why a contractor would be foolish to bid without an associate of "influence." But taking the country, near and far, the only "pull" that is really beneficial is personal acquaintance with those in charge of work. Say what we may about judicial fairness in interpreting specification clauses that do not specify, the

fairness is more apt to be shown by friends than by strangers.

Believing then that a public works contract can usually be secured by bidding low enough, the young contractor may still have doubts as to his ability to secure bondsmen. No man should put in jeopardy the property of his friends by asking them to go on his bonds for a contract. It matters not how sure he may be of himself and of his ability to execute the work at a profit, for he should bear in mind that a strike beyond his control may upset all calculations. Furthermore, the young man's own estimate of himself is apt to have an optimistic tint, to say the least. A surety company should be consulted, and it is well to go to such a company at first with only a small contract for which bondsmen are desired. Be prepared to give them in detail your experience and your financial resources, exaggerating neither; for, in case of subsequent failure, criminal proceedings may be brought against a man who has misrepresented his resources. If you have but little cash capital, frankly say so, but be prepared to show in detail how you purpose doing the work with the funds available. Suppose you expect to have a $5,400 earth work job to do; that you will have 12 weeks in which to do it, with two weeks margin for delays, etc.; and that payments of 85 per cent of the estimated value of the work done are to be made monthly, and you purpose beginning the work the middle of the month. You estimate the work to cost $4,800, hence your weekly pay-roll will be $400 if the work is done in 12 weeks. You are to pay your men every two weeks, hence you need only $800 in cash to carry you until the first of the month, and as your contract calls for the monthly payment to be made before the 10th day of the month, you can count upon receiving $765 (85% of one-sixth of $5,400) in time to apply on the next pay roll. Your cash capital to start with is $1,800, or practically twice as much cash as will carry the work, in case there are no unforeseen delays, and in case you have not underestimated its cost. If you are able to persuade the surety company's representative that your estimate of actual cost of the work is reliable there should be no difficulty in securing their agreement to act as your bondsmen. The writer has

found a great difference in surety companies; some going into the details of a contractor's project as if they expected to be a partner in the business; others, on the contrary, giving only a superficial study of the project. If you have perfect confidence in your estimates, select the surety company which goes into details most thoroughly. Their judgment in future contracts may be of great value to you, by saving you from yourself. The time will come when every reliable surety company will employ agents who are themselves engineers skilled in estimating costs as well as in estimating reputations.

After a contractor has done enough work, even though the jobs be small, to prove that he is a trustworthy man, he may go with confidence to the banks in the locality where he is known, and upon his note secure enough money to undertake larger contracts. If a certified copy of the monthly estimate can be secured from the engineer, it is usually possible to get a banker to advance the cash upon it before the day of payment. This is often a matter of some importance; in fact, the writer has known three weeks, or more, to elapse after the first of the month before the check for the last month's work arrived, and, when the contractor is loaded up with work requiring the expenditure of considerable sums for labor and materials, such delays are often serious, or at least very annoying. Do not wait, therefore, until such a delay forces you to go to a bank to borrow a large sum of money on the engineer's certificate of work done, but make it a practice to borrow occasionally on small monthly estimates even when you do not really need the money. It is a trait of human nature, and particularly of human nature in the banking business, to look with suspicion upon a sudden demand for the loan of a large sum of money under conditions that previously have not required the use of credit. If, however, the banker has become accustomed to advancing small sums from time to time upon monthly estimates, he is not surprised when larger sums are asked for under similar conditions, and will not ordinarily refuse. A young contractor once told the writer that he established a reputation for promptness in paying his notes by borrowing money that he did not use at all, but simply stored in a strong box until a

few days before the maturity of the note, when he stepped into the bank, made a deposit and promptly paid his note the day before its maturity. He found it well thus to invest some of his money, and eventually bought a reputation for a promptness in meeting obligations that enabled him to borrow large sums when he really needed them. However one may view this practice, it indicates clearly the value of asking credit on a small scale, meeting obligations promptly, and thus establishing a precedent both for the banker and for yourself to follow on a larger scale.

We have touched upon the method of estimating the amount of money necessary to handle a contract of given size which must be finished in a given time, but a few words more may not be amiss.

It ordinarily requires far more cash capital to handle work in which the pay roll is the main item, than work in which bills for materials are the main items of cost. Laborers must usually be paid as often as once in two weeks, in some places once a month and in others once a week. Material, such as stone, timber, cement, etc., may ordinarily be purchased on time, the time varying from 30 to 60 days. Aside from the advantage derived by having a longer time in which to secure money from monthly estimates, it is well to remember that material men will not go on a strike if pay day is delayed a few days. This is often a "life saver" at periods of unexpected distress. In any case, materials will usually pay for themselves if they can be put into work promptly upon arrival. On the other hand, it often happens that materials are delivered weeks before they can be used, and if the contract does not require the engineer to allow in his monthly estimate for "materials delivered," the contractor may be compelled to pay for the materials long before he can receive payment. Here, again, the banks will assist him, if he has made it a practice to borrow money upon "materials delivered." Certainly, under such conditions, "materials delivered" belong to the contractor, and they form an asset which, added to the contractor's personal reputation, will serve as security for a loan.

Where large quantities of purchased materials will be required, the contractor should ascertain either by study-

ing the specifications or by direct inquiry of the highest officials whether "materials delivered" will or will not be included in monthly estimates. If engineers knew how often their refusal to estimate "materials delivered" results in tardy deliveries in small lots, possibly the practice of paying monthly for "materials delivered" would be everywhere followed. Whether contracting firms are large or small, the tendency is to take as much work as their cash capital will enable them to handle. Mere size, therefore, does not always mean unlimited credit, and if a large firm is working nearly up to the capacity of its credit, it is quite as likely to be embarrassed as a small firm by delay in payment for "materials delivered" as well as for work done.

PART V.

The failure of many business enterprises is not due so much to a lack of knowledge of proper business rules and principles as to a lack of persistence in the application of those rules and principles. It is easier to reason out a mode of procedure than to follow it, the tendency being always to trust to luck in too great a measure, and to defer the application of the rule. For example, an employer of men observing that men work with greater energy when they are paid a bonus, deduces the following rule: It pays to share the profits with the employees when they especially exert themselves. But, having come to a logical conclusion, the employer often stops there. He may excuse himself on the ground that the work he has in hand is of a class to which it is exceedingly difficult to apply any such rule, or, what is more likely, he may consider himself an exception among managers and determine to drive the men without giving up any part of his prospective profits. In any case, he will probably find that without some direct and immediate monetary gain, employees will not do their best.

In introducing any bonus system, it is best to begin with the foremen, for being more intelligent they will more quickly respond to any such encouragement. If you are crushing rock, for example, there should be some system of tallying either loads delivered or the loads removed each day. The man who is running the crushing plant should

be required to report daily, giving the output and the time lost, if any, due to breakdowns, etc. Reports of progress should always be daily reported. The reason for this is that few men look far enough ahead to be spurred to action when the work is measured up only once a week or once a month. These daily reports should be made on mimeographed or printed blanks which require only the slight labor of filling in with the figures showing the work done and the force employed. A mimeograph will soon save its cost; and it enables a contractor to get out new forms of blanks at a moment's notice, without waiting for a job printer. When the reports are received at the central office they should be recorded in such form as to make it easy to compare the progress from day to day.

Assuming that the average output of a crusher has been 60 cu. yds. per day under the ordinary methods of working, it will probably be possible to increase the output by 20% upon offering a fair bonus for each yard over 60. Make the experiment first by offering to the man in charge a bonus of, say 10 cts. per cu. yd., for all over 60 cu. yds. per day, and note the result. If there is no adequate return, it may be well to change foremen, or dispense with a foreman entirely and divide the bonus among the laborers. As a matter of fact, this latter procedure often yields surprisingly good results; for, if the expense of an idle foreman can be eliminated, there will be a saving of 5 to 15% in the cost of doing the work, so that the money expended as a bonus yields not only an increased output of the plant, but reduces the cost of supervision. There are, and always will be, classes of work requiring the constant attention of foremen, and in such cases it will usually be found best to give half or perhaps all of the bonus to the foreman. On the other hand, where the foreman acts merely as an overseer to prevent shirking of duty, it is frequently possible to dispense with him entirely by introducing the bonus system.

Whether the bonus system is used or not the work should be laid out, wherever possible, so that there will be competing gangs of men. In laying the concrete foundation of a pavement, for example, assign one-half the street, from the center to the curb, to one gang of men, and the other

half to another gang. The rivalry so engendered will invariably lead to faster work. The larger the gangs of men the more desirable does it become to work thus in rivalry, even where the bonus system is used; for wherever there is a large gang there are sure to be some naturally lazy men whom no amount of bonus can induce to work at a reasonably fast rate. Moreover, the larger the gang the less interest does each man feel in the bonus, hence the desirability of supplying further stimulus, such as rivalry supplies.

Perhaps the most striking example among business men of success that has attended profit-sharing is to be seen in the person of Andrew Carnegie. He has not only made millions for himself, but he has made great sums for the ablest of his employees. Had he attempted to "hog it all," there is every reason to believe that the most ambitious, and consequently the best of his employees would have left him from time to time, some of them to start in a competitive business for themselves, others to become employees in competing firms. The bonus system is a system of profit-sharing, and it is surprising to find certain labor unions arrayed against it. It is a system that tends to reduce the amount of supervision to a minimum, and, as all men dislike being "bossed," the wonder is that any laborers are to be found to oppose it. Perhaps the trickery of employers is largely responsible for the opposition to this form of profit-sharing, for it often happens that an employer, upon finding that his men produce with greatest ease at least 25% more under the bonus system, decides to keep the biggest part of this increased production himself by cutting down the rate of bonus paid. Not without reason, therefore, does the laborer say that the bonus system will lead to harder and harder work with no reasonable increase in wages. Possibly the really useful function of the labor unions of the future will be to hold employers to their implied agreements in the matter of profit-sharing under a bonus or premium system, for it certainly is rank trickery to induce men to work harder by an offer of a share in the profits only to seize the lion's share and leave them little more than before.

An expedient worth considering, where several gangs

of men are working under different foremen, is the plan of changing the foremen about. This was done with excellent results in driving a tunnel near the City of Mexico. After the work has been well organized, it is possible thus to shift the foremen from week to week, or from month to month, without disorganizing the gangs. The advantage of such shifting lies in the fact that familiarity breeds leniency. The foreman who will be exacting with strange men will often become "a good fellow" after a short time, and the result is that the output of the men under him falls off. The writer has often noticed that foremen who would secure an output of 15 cu. yds. of earth loaded per man per day for the first two weeks on a job, would after that slowly relax until a falling off of 20% or more in output occurred. It is well usually to have foremen who are strangers to the men, and to see that they remain strangers.

Another expedient that was also tried on the above mentioned tunnel work was the working of broken shifts; that is, the men worked four hours, then laid off four hours while another gang took their places, and then returned to work four hours more. By this means the progress of the tunnel driving was increased about 50%. Doubtless this method would show better results with such workers as are found in southern climates than with workers in the north. Still there is good reason for believing that it would prove effective wherever men are willing to work intermittently. By paying some bonus for progress it may be possible to induce men to work thus, for then their interest in making progress is identical with that of their employer. Of course where men are running machines, like air drills or steam shovels, there is little to be gained by such a method of working; but men doing hard physical labor would doubtless accomplish more by working vigorously for a half shift and then taking a long rest before finishing their shift.

Wherever a contractor is working in the country he should have his own lodging camp at which all men should be required to lodge. The object of this is not to make money by renting bunks, but to be in a position to make strikers leave the country entirely, if strikes occur. For the same reason, a company store should be kept by the

contractor, if he does not board the men. To be able thus to cut off the source of supplies of the opposition is often the only way of breaking up a strike. A contractor having based his estimate of cost upon ruling wages is often most unjustly attacked by his men who seek an increase in wages which if granted would mean his ruin. Laborers do not consider that side of the matter at all, and the more lenient and "white" the contractor has been the more likely is a strike for increased wages to occur. By being foresighted a contractor can usually bring a strike to a sudden end, or prevent it entirely when his work is not near the permanent residences of the strikers. On large work a few detectives among the workers (detectives who are workers themselves and are old and trusted employees) will give the first hint of talk about striking. Then is the time to act, and not after the talk has ripened into resolution. Immediately shake up the forces; lay off part of the gangs, including some who are not agitators along with the agitators. Let it be known by rumor that the introduction of more machinery is contemplated in order to dispense with hand labor, and what is more, rush some machinery in even if it does not pay directly to do so, and even if it does not replace the men laid off. War tactics must be met in kind. A strike is a labor war, and a strike against a contractor is usually a treacherous attack. If the employees of a factory strike for higher wages and win, the manufacturer usually makes the public foot the bill in the end; certainly where such strikes are general, he does. But a contractor is virtually robbed by a strike occurring after he has begun work. If footpads were to hold him up and take his money he would be better off, for then at least he would have some chance of recovering it. The foregoing statements are all based upon the assumption that the contractor is paying rates of wages that were standard in the place and at the time of the letting of the contract.

If labor unions were to give notice that their members would not work under contracts taken on and after a certain date, at less than a certain wage, contractors would then simply "figure accodingly." As it is, however, such fair action is seldom taken. Perhaps this is another feature

that the labor unions of the future may consider with profit. At present the contractor must protect himself as best he can by the exercise of forethought, for it is forethought that gives to the leaders of men a power not possessed by the men they lead.

SECTION II.

COST OF EARTH EXCAVATION.

Earth Measurement.—Earthwork is paid for by the cubic yard, and is usually measured "in place," that is, in the natural bank or pit before it has been loosened. The price paid usually includes the excavating, hauling and placing the earth in the embankment, and no extra price is paid for making the embankment—in other words, the earth is paid for but once Occasionally, in dike work, in building reservoir embankments, and wherever it is very difficult to measure the earth in place, it is specified that the earth shall be measured in the consolidated embankment. However, unless otherwise stated, all costs given in this book refer to measurements of earth in place.

Many specifications for railroad work contain an "overhaul clause," which provides that for all earth hauled more than a certain specified limit, the contractor shall be paid a certain amount per cubic yard, usually 1 ct. per cu. yd. per 100 ft. overhaul. The specified limit of "free haul" is sometimes 1,000 ft., sometimes 500 ft. Even in case of an overhaul, no additional payment is made for building the embankment, but only for the overhaul.

Earth Shrinkage.—Earth when first loosened and shoveled into a wagon swells, that is, it occupies more space than it did "in place"; but, when placed in an embankment and rolled or pounded down, it shrinks, and this shrinkage is often so great that the earth occupies less space in the embankment that it did "in place." The following is a summary, based upon data of actual tests given in my book on earthwork:

1. Taking extreme cases, earth swells when first loosened with a shovel, so that after loosening it occupies $1\frac{1}{7}$ to $1\frac{1}{2}$ times as much space as it did before loosening; in other

words, loose earth is 14% to 50% more bulky than natural bank earth.

2. As an average, we may say that clean sand and gravel swell 1/7, or 14% to 15%; loam, loamy sand or gravel swell 1/5, or 20%; dense clay, and dense mixtures of gravel and clay, ⅓ to ½, or 33% to 50%, ordinarily about 35%; while unusually dense gravel and clay banks swell 50%.

3. Loose earth is compacted by several means; (a) the puddling action of water, (b) the pounding of hoofs and wheels, (c) the jarring and compressive action of rolling artificially.

4. If the puddling action of rains is the only factor, a loose mass of earth will shrink slowly back to its original volume, but an embankment of loose earth will at the end of a year be still about 1/12, or 8%, greater than the cut it came from.

5. If the embankment is made with small one-horse carts, or wheel scrapers, at the end of the work it will occupy 5 to 10% less space than the cut from which the earth was taken, and in subsequent years will shrink about 2% more, often less than 2%.

6. If the embankment is made with wagons or dump cars, and made rapidly in dry weather without water, it will shrink about 3% to 10% in the year following the completion of the work, and very little in subsequent years.

7. The height of the embankment appears to have little effect on its subsequent shrinkage.

8. By the proper mixing of clay or loam and gravel, followed by sprinkling and rolling in thin layers, a bank can be made weighing 1¾ times as much as loose earth, or 133 lbs. per cu. ft.

9. The bottoms of certain rivers, banks of cemented gravel, and hardpan, are more than ordinarily dense, and will occupy more space in the fill than in the cut unless rolled.

Kinds of Earth.—Earth may be divided into three classes as regards difficulty of excavation: (1) Easy earth; (2) average earth; and (3) tough earth. To the first class belong loam, sand, and ordinary gravel, which require little or no picking to loosen ready for shoveling. To the

second class belong sands and gravels impregnated with an amount of clay or loam that binds the particles together, making it necessary to use a pick or a plow drawn by two horses to loosen the earth before shoveling. To the third class belong the compact clays, the hardened crusts of old roads, and all earths so hard that one team of horses can pull a plow through the earth only with greatest difficulty, but that two teams of horses on one plow can loosen with comparative ease.

This third class of earth passes by insensible degrees into what is called "hardpan." Hardpan commonly means a very compact clay, or mixture of gravel or boulders with clay. Soft shales that can be plowed with a rooter plow are sometimes called hardpan. There are also certain gravels cemented with an iron oxide (iron rust) which are called hardpan.

There are many local names applied to different kinds of earth. "Adobe" is a name much used in Texas, Arizona, California and neighboring states to denote any clay of which mud bricks, or adobes, might be made. "Gumbo" is a word used in the Mississippi Valley to denote a black loam containing so much clay as to be exceedingly sticky when wet. "Marl" is, strictly speaking, a mixture of clay and pulverized limestone, but the term is often applied to clay soils containing only 1% to 2% of limestone dust, as, for example, the greensand marls of New Jersey. There are many local deposits of disintegrated minerals, which, when soapy in texture, are often called marl. In some cases these deposits are so greasy that, when saturated with water, slides and cave-ins occur when an attempt is made to excavate them.

Quicksand is a term applied to any sand, or sandy material, which flows like molasses when the sand is saturated with water.

In this book the rules for estimating costs, unless otherwise stated, relate to "average earth," as above defined.

Definitions of Haul and Lead.—"Lead" is a term used to denote the horizontal distance in a straight line from the center of mass of the pit to the center of mass of the dump. The pit, in this case, refers to the volume of

earth to be excavated, and the dump refers to the embankment. The "lead" does not include the distance actually traveled, including turnouts, etc., from pit to dump; this actual distance traveled by the cars or wagons is called the "haul." The "haul" is then half the distance traveled by a car or wagon in making a round trip.

Work of Teams.—A "team," as used in this book, means a pair of horses *and* their driver. Even where the word driver is omitted in speaking of the cost of team work, the wages of the driver are always included under the word "team." A good average team is capable of traveling 20 miles in 10 hrs., going 10 miles loaded and returning 10 miles empty, over fairly hard earth roads. If the team is traveling constantly over soft ground, 15 miles is a good day's work. On the other hand, if the team is traveling over good gravel or macadam roads, or paved streets, it is possible to average 25 miles per 10-hr. day. These rates include the occasional stops made for rests, etc., and include the climbing of an occasional hill.

When traveling at the rate of 2½ miles an hour, which is the ordinary walking gait of horses, the distance covered in 1 min. is 220 ft. Over good hard roads a team may trot with an empty wagon at the rate of 5 miles per hr., and thus make up for delays in loading and unloading, so as to cover the full 20 miles of daily work; but over soft ground a team should not trot.

The loads that a team can haul (in addition to the weight of the wagon) over different kinds of roads are as follows:

	Short Tons.	Earth, cu. yds.
Very poor earth road................	1.0	0.8
Poor earth road	1.25	1.0
Good hard earth road	2.0	1.6
Good clean macadam road	3.0	2.4

It is not possible to haul much greater loads over an asphalt or brick pavement than over a first-class, clean macadam. On all the kinds of roads to which the above averages apply, there were occasional steep grades to ascend, and occasional bad spots to pass over.

The pulling power of a horse averages about one-tenth of his weight when exerted steadily for 10 hrs.; that is, a 1,200-lb. horse will exert an average pull of 120 lbs. on the traces. But for a short space of time the horse can exert a pull (if he has a good foothold) equal to about four-tenths his weight, that is, fcur times his average all-day pull. This I have tested with teams, not only in ascending steep grades but in lifting the hammer of a horse-operated pile driver.

Where teams are traveling long distances, it is customary to have two wagons keep together, so that one team can help the other up a steep hill by acting as a "snatch team." A "snatch team," or helping team, may often be kept busy to advantage in pulling heavily loaded teams out of a pit, or onto a soft embankment, or up a steep grade. Three-horse snatch teams are frequently used. A small hoisting engine may replace a snatch team to advantage in many places. By laying channel irons for rails up a steep hill, and having a hoisting engine at the top, very heavy loads can be assisted over bad roads. In this case, a boy mounted on a pony can drag the hoisting rope back to the foot of the hill ready for the next team. Plank roads can often be built to advantage for short distances up steep grades, or over bad spots.

In the far West it is customary for three or more teams to be hitched to a train of two or more wagons; and, when a steep hill is to be ascended, to haul one wagon up at a time. This saves wages of drivers.

Cost of Maintaining Teams.—The writer has maintained teams at the following cost per month per team of two horses:

½-ton of hay, at $10	$ 5.00
30 bu. oats, at 35 cts.	10.50
Straw for bedding	1.00
Shoeing and medicine	2.00
Total	$18.50

A generation ago there were 2,000 horses used on the Brooklyn street railways. The cost of feeding each horse

was $10 a month, and the depreciation in value of each horse was 25% per annum.

Contract work is not so severe as street car work; still the annual depreciation is probably not less than 15%. A team, wagon and harness costing $300 should be charged with about $60 per annum for interest and depreciation. When the team is working it must be fed oats, when not working it can be fed on hay at half the usual cost.

The following gives the average feed of horses and mules used by the H. C. Frick Coke Co., extending over a period of 6 years; 500 lbs. of hay, 7 bushels of oats, 4⅗ bushels of corn on the ear, per head per month. The daily feed of each animal was two feeds of corn, 13 ears to the feed (70 lbs. per bu.), one 6-quart feed of oats, and about 16½ lbs. of hay. Each animal averaged about 13 miles traveled per day underground, 15 miles being the maximum 10-hr. day's work. It will be observed that this feeding agrees very closely with the writer's experience.

It is not ordinarily possible to get more than 180 days of work per annum out of a contractor's team in the North, and very frequently much less. We may, therefore, say that $1.50 for each day actually worked by the team will cover its feed, interest and depreciation, for the year. If the driver is paid only while at work, then his $1.50 added to that of the team makes $3 a day for each day worked.

The cost of feeding 25 horses at work building roads near San Francisco, for a period cf 12 mos., was as follows, per horse per day:

28 lbs. wheat hay, at $15.50 per ton	$0.215
12 " rolled barley, at $24.10 per ton	0.150
1½ " oats, at $27.40 per ton	0.020
¼ " bran, at $21.20 per ton	0.003
1⅓ " straw bedding, at $13.80 per ton	0.009
Wages, 1 stableman ($775 for year), and hauling forage ($281 for year)	0.113
Total per horse per day	$0.510

The above shows a consumption of nearly 42 lbs. of feed per horse per day, which seems large, but is not excessive

for heavy draft horses working daily. A conservative estimate of the food waste is 5%.

A four-horse team averaged 16½ miles traveled per day over fair macadam roads with some 5% grades. The load was 3 short tons, plus the 0.65-ton wagon; and the haul, one way, was ½ to 1 mile.

Cost of Plowing.—A team on a plow will loosen 500 cu. yds. of loam, or 350 cu. yds. of loamy gravel, or 250 cu. yds. of fairly tough clay, per 10-hr. day. For "average earth," therefore assume 350 cu. yds. per day loosened by a team and driver and one man holding plow. With wages at $3.50 for team and driver, and $1.50 for laborer, the cost of plowing average earth is 1½ cts. per cu. yd.

In plowing very tough material with a pick-pointed plow, four horses and three men, estimate 180 cu. yds. plowed per day at a cost of 5 cts. per cu. yd.

Cost of Picking and Shoveling.—When wages are $1.50 per 10-hr. day, the cost of loosening earth with a pick (instead of a plow) ranges from 1 ct. per cu. yd. for very easy earth, to 11 cts. per cu. yd. for very stiff clay or cemented gravel; for "average earth" the cost of picking is about 4 cts. per cu. yd.

The cost of loosening with a pick and shoveling into wagons is as follows, wages being 15 cts. per hr.:

	Per cu. yd.
Easy earth, light sand or loam	12 cts.
Average earth	15 "
Tough clay	20 "
Hardpan	40 "

The amount of earth that a man can load with a shovel varies with the character of the earth, the way it has been loosened, the size and shape of the shovel, etc. If a man is shoveling earth from the face of a cut that has been undermined and broken down with picks, he can readily load 18 cu. yds. per 10-hr. day, after the earth has been loosened. If he is shoveling plowed earth, where he must use more force in driving the shovel into the soil, he will easily load 14 cu. yds. of average earth in 10 hrs. If he is shoveling

loose earth off boards upon which it has been dumped, he can load 25 cu. yds. in 10 hrs., but it is not wise to count on more than 20 cu. yds. even under good foremanship.

For data on the cost of trenching, the reader is referred to the sections on Sewers and on Water-works.

Cost of Trimming, Rolling, Etc.—After earth has been dumped from carts or wagons, a man will spread in 6-in. layers by hand 75 cu. yds. in 10 hrs., at a cost of 2 cts. per cu. yd. A leveling scraper, or road machine, will spread large quantities of earth for ½ ct. to ¾ ct. per cu. yd. With a Shuart grader (or leveling scraper) operated by a team and driver and a helper, the author has had 500 cu. yds. spread per day. A road machine, operated by 6 horses and 2 men, will spread 900 cu. yds. in 10 hrs. in 6-in. layers, earth having been dumped from patent dump-wagons.

A man can thoroughly tamp 25 cu. yds., in 6-in. layers, per 10-hr. day at 6 cts. per cu. yd. Embankments can be consolidated with horse-drawn rollers for ½ to 1 ct. per cu. yd., wages of a team being $3.50 a day. I have one record of 3 cts. per cu. yd. (at the above wages), for rolling a reservoir embankment, but the work was not well handled.

The cost of sprinkling embankments, if specified, is difficult to estimate because of the vagueness of specifications. However, more than 8 cu. ft. of water per cu. yd. of earth, is seldom required.

On a large embankment three sprinkling carts, each drawn by three teams, with one driver, sprinkled 1,000 cu. yds. of earth per day of 10 hrs., with short haul. Such carts each held 150 cu. ft. of water weighing 4½ tons, which is an exceedingly large capacity. A sprinkler of this size can be loaded from a tank in 15 mins., and emptied in the same length of time. Knowing the length of haul and speed of team the cost of sprinkling is readily determined. In the case just given the cost was 2¼ cts. per cu. yd. cf earth for sprinkling and about 5 cu. ft. of water per cu. yd. were used.

From several careful observations the writer has found that a gang of men under a good foreman will each trim the sod and humps off the hard surface of a cut to the depth of 1 or 1½ ins. at the rate of 200 sq. ft. or 22 sq. yds. per

hour, at a cost of $^{2}/_{5}$-ct. per sq. yd.; and where there was no sod to remove, the soil being sandy loam, the cost was one-half as much or ⅓-ct. per sq. yd. Massachusetts contractors bid almost uniformly 2 cts. a sq. yd. for "surfacing" (wages 17 cts. per hour), which includes rolling the finished surface with steam roller. A roadway, including ditches, 36 ft. wide and a mile long, has 21,000 sq. yds. of surface, which, at ⅔-ct. is $140, actual cost of trimming. If the total excavation in a mile is 3,500 cu. yds. (which is about the average in N. Y. State), the cost of trimming, distributed over this 3,500 cu. yds., is 4 cts. per cu. yd. of excavation, a cost much greater than a mere guess would lead one to suppose. The author has directed the scraping of a light growth of weeds and grass off the 4-ft. shoulder of a road by going once over it with a Shuart grader, at a rate of 200 sq. yds. per hour, or ten times faster than a man with a mattock would have done it; making the actual cost about ¼-ct. per sq. yd. where the team, driver and helpers' wages were 50 cts. per hour.

Cost of Wheelbarrow Work.—A man wheeling a barrow over run-plank can not be counted on to travel more than 15 miles per 10-hr. day. If the runway is level a load of 300 lbs. or more may be wheeled in a barrow, but it is not safe to count upon more than 250 lbs., or $^{1}/_{10}$ cu. yd. of earth. This is for good level runways, but, as most wheelbarrow work involves ascending steep grades, estimate $^{1}/_{14}$ to $^{1}/_{15}$ cu. yd. per barrow load. With wages at 15 cts. per hr., the cost of wheeling earth in barrows is, therefore, 5 cts. per cu. yd., per 100 ft. of haul, the haul being the distance from pit to dump. If the runways were level, and the men worked hard, the cost might be reduced to 3 cts. per cu. yd. per 100 ft. of haul.

The cost of picking and loading has already been given, and may be assumed to be 15 cts. per cu. yd. A wheelbarrow is dumped in about ¼ min., which is equivalent to a loss of nearly 4 mins. per cu. yd., where 15 barrow loads make a yard; and this is equivalent to 1 ct. per cu. yd. for dumping the barrows. The time lost in changing barrows, etc., may easily add another 1 ct. per cu. yd. The rule for estimating the cost of loosening, loading and haul-

ing average earth in barrows is as follows when wages are 15 cts. per hr.:

Rule I.—To a fixed cost of 17 *cts. per cu. yd., add* 5 *cts. per cu. yd. per* 100 *ft. of haul.*

Cost by One-Horse Carts.—Small two-wheeled carts drawn by one horse are often used on railway work. If the haul is level or slightly down hill and over a well compacted embankment, a horse will pull 0.6 cu. yd. per load; but over poor earth roads it is not safe to count upon more than 0.4 cu. yd. per load, if there are any steep grades to ascend. On short hauls of 300 ft. or less, one driver can tend to two carts by leading one to the dump while the other is being loaded. A gang of 4 or 5 men should load a cart with 0.4 cu. yd. in 3 mins., and it takes about 1 min. to dump a cart, so that 4 mins. of cart time are "lost" every round trip. If the wages of a horse are $1 per 10-hr. day, and the wages of a driver are $1.50 a day, the wages of a cart and half a driver are $1.75 a day. The 4 mins. "lost time" is therefore equivalent to 3 cts. per cu. yd. The cost of picking and loading average earth is about 15 cts. per cu. yd., as previously given. A dumpman can easily dump a cart load a minute, where he has no spreading to do; but the material is seldom delivered fast enough. If we assume 150 cu. yds. delivered to him in carts in 10 hrs., the cost is 1 ct. per cu. yd. for dumpman's wages. Hence the total fixed cost may be assumed as 15 + 3 + 1 ct., or 19 cts. per cu. yd. If the cart load is 0.4 cu. yd., and wages are as above given, we have the following rule:

Rule II.—To a fixed cost of 19 *cts. per cu. yd. add* ¾*-ct. per cu. yd. per* 100 *ft. of haul.*

If the material is plowed, and is shoveled easily, the fixed cost may become 14 cts. per cu. yd. instead of 19 cts.

If the haul is long, one driver may still attend to two carts by taking them both together to the dump. There are occasions, however, when one driver attends to only one cart; in such cases the cost of hauling is 1 ct. per cu. yd. per 100 ft.

In cities, where the carts travel over hard earth or gravel roads, a cart carrying ⅔ cu. yd. may be used. The cost of

hauling is, then, ½-ct. per cu. yd. per 100 ft. of haul, wages of cart and driver being 25 cts. per hour.

Cost by Wagons.—There are three types of four-wheeled wagons commonly used by contractors: (1) The slat-bottom wagon; (2) the bottom-dump wagon; and (3) the end-dump wagon. Any farmer's wagon can be made into a slat-bottom wagon by removing the wagon box and replacing it with "slats" of 3 × 6-in. sticks for a bottom, and 2 × 12-in., or 2 × 16-in., planks for sides and ends. The bottom-dump, or "patent dump-wagon," has a bottom consisting of two doors that swing downward in dumping. The end-dump wagon dumps backward like a two-wheeled cart. The best makes of this type of wagon are provided with a geared device by which the dump-man slides the wagon box bodily backward over the axle of the rear wheels until it tips and dumps its load.

The loads that are commonly hauled in a wagon by one team are given on page 76.

To reduce the lost time in loading wagons a common expedient is to provide extra wagons which are loaded while the teams are on the road to and from the dump. A team can be changed from an empty wagon to a loaded wagon in 1 to 1½ mins.

Three horses should be used on each wagon far oftener than they are used on contract work, as nearly 50% more material can be hauled per load than with two horses. In the far West, one often sees two teams (four horses) hitched to a wagon, even on short haul work.

One man aided by the driver can dump a slat-bottom wagon holding 0.8 cu. yd. in 1½ mins., at a cost of 0.4 ct. per cu. yd. for the dumpman's time and 1 ct. per cu. yd. for lost time of team, wages being 15 cts. per hr. for dumpman, and 35 cts. per hr. for the team. It takes 3 mins. for these men to dump a large slat-bottom wagon holding 1½ cu. yds., where the driver removes the seat before dumping and replaces it afterward. So that in either case we see that the cost of dumping is about 1½ cts. per cu. yd. If a binder chain is wound around the wagon box to hold the slats close together so that no earth will spill through onto a street pavement, it takes 5 mins. to dump the wagon.

The time required to dump a drop-bottom wagon is practically nominal, and the driver dumps his own wagon.

It takes about 1 min. for the dumpman and driver to dump an end-dump wagon.

In loading wagons there are usually enough men provided in the pit to load 1 cu. yd. into a wagon in 4 or 5 mins. or less. This is equivalent to 2½ to 3 cts. per cu. yd. for lost team time in the pit, which, added to the lost team time at the dump, gives us about 4 cts. per cu. yd. where slat-bottom wagons are used. The cost of the dumpman's time will never be much less than ½ ct. per cu. yd.; and, if the material is not delivered rapidly, it may be much more.

The cost of excavating and loading has been given in previous pages. If we assume this cost to average 13 cts. per cu. yd., where the earth is plowed, and add 5 cts. for lost team time and dumping, we have a fixed cost of 18 cts. per cu. yd. Then the cost of hauling will depend upon the size of the load, and, assuming wages of team at 35 cts. per hr., and speed of travel 2½ miles an hour while actually walking, we have the following rule:

Rule III.—To a fixed cost of 18 cts. per cu. yd., add ½ ct. per cu. yd. per 100 ft. haul when the wagon load is 1 cu. yd.

For other wagon loads use the following:

	Per cu. yd. per 100 ft.
Load being 0.8 cu. yd., add	0.66 ct.
Load being 1.0 cu. yd., add	0.53 ct.
Load being 1.6 cu. yds., add	0.33 ct.
Load being 2.0 cu. yds., add	0.26 ct.
Load being 2.4 cu. yds., add	0.22 ct.

In round numbers, therefore, for a load of 1 cu. yd. we must add ½ ct. per cu. yd. per 100 ft. haul, or 28 cts. per cu. yd. per mile haul, wages of team being 35 cts. per hr.

Cost by Drag Scrapers.—A drag scraper is a steel scoop, not mounted on wheels, for scooping up and transporting earth short distances, and is drawn by a team. The ordinary No 2 drag scraper weighs 100 lbs., and is listed in catalogues as holding 5 cu. ft. of earth. The actual average load, however, is about 1-9 to 1-7 cu. yd. place measure.

In working drag scrapers on short leads there are usually three teams traveling in a circle or ellipse of 150 ft. circumference. One man loads the scrapers in the pit as they go by, and each driver dumps his own scraper. When the gang is working properly, the actual speed of the teams is 2½ miles an hour, or 220 ft. per min., while actually walking; and the "lost time" in loading and dumping is ⅓ to ½ min. per trip, or, say, 3½ mins. per cu. yd., which is equivalent to 2 cts. per cu. yd. for lost team time when team wages are 35 cts. per hr. The man loading can readily load 1,500 scrapers per day, or, say, 180 cu. yds., so that the cost of loading is about ¾ ct. per cu. yd. The cost of plowing (see page 79) will average 1¾ cts. per cu. yd. As above stated, the teams travel in a circle, and, no matter how short the "lead," room must be allowed for turning and manoeuvering the teams; this room is approximately 50 ft. at each end of the haul, so that we have 100 ft. of extra travel, or nearly ½ min. of time for each trip, in addition to the "lead." This ½ min. adds another 2 cts. per cu. yd. Summing up, we have the following fixed cost, exclusive of foreman's wages:

	Per cu. yd.
Lost team time loading and dumping	2 cts.
Wages of man loading	¾ "
Plowing	1¾ "
Extra travel of team in turning, etc.	2 "
Total fixed cost	6½ "

If the average load is 1-7 cu. yd., hauled at a speed of 220 ft. per min., the cost of hauling is 4½ cts. per cu. yd. per 100 ft. of "lead." Note that this "lead" is measured on a straight line from center of pit to center of dump. The rule, then, is as follows for "average earth" when team wages are 35 cts. per hr.:

Rule IV.—To a fixed cost of 6½ cts. per cu. yd. add 4½ cts. per cu. yd. per 100 ft. of "lead."

This is approximately equivalent to 1 ct. added for each 25 ft. of "lead." Thus, if the "lead" is 25 ft., the cost of drag scraper work is 6½ + 1, or 7½ cts. per cu. yd.

The cost of foreman's wages is ordinarily about ¾ ct. per

cu. yd., and wear on scrapers, etc., will add another ¼ ct. per cu. yd.

The cost of excavating and hauling fairly stiff clay may easily be 30% more than the above costs for "average earth."

Cost by Wheel Scrapers.—The wheel scraper is a development of the drag scraper, being a steel scoop low hung between two wheels. The following are common sizes of wheelers:

	Weight, lbs.	Capacity. Listed, cu. ft.	Capacity. Actual Struck Measure, cu. ft.
No. 1	340—450	9—10	7½—9
No. 2	475—500	12—13	8¾
No. 2½	575	14	12
No. 3	625—800	16—17	15½

The "listed" capacity is the capacity given in catalogues. The "actual struck measure" capacity is the exact contents of the bowl when level full of loose earth, and it should be remembered that about one-fifth or 20% should be deducted from this to get the actual struck capacity of earth measured "in place" before loosening.

Large wheelers, even in light soils, and small wheelers in tough soils, seldom leave the pit full of earth, but at the back end of the bowl there is usually a wedge-shaped unfilled space. The author has found the average load, "place measure," carried by wheelers is as follows:

No. 1	1/5 cu. yd.
No. 2	¼ " "
No. 2½	⅓ " "
No. 3	4/10 " "

A snatch team, to assist in loading, is generally used with a No. 2 wheeler, and always with a No. 3 wheeler.

On long hauls it is advisable to have men with shovels to heap the bowl full of earth, using a front gate on the wheeler to prevent loss of material in transit.

The lightest No. 1 wheelers made are to be recommended where leads are very short and rises steep, that is, wherever drag scrapers are ordinarily used, for they move earth more economically than drags. Where soil is very stony, or full of roots, drag scrapers are to be preferred, since they are

more easily and quickly loaded under such conditions. With wheelers, as with drag scrapers, add 50 ft. to the actual "lead" for turning and manoeuvering the teams, equivalent to half minute of team time each trip. Another half minute is lost in loading and dumping.

The fixed costs for the three common sizes of wheelers are as follows for "average earth," when wages are 15 cts. per hr. for laborers and 35 cts. per hr. for teams:

	Cents per cu. yd.		
	No. 1.	No. 2.	No. 3.
Lost team time loading and dumping..	1.5	1.2	0.8
Wages of man loading	0.8	0.8	1.5
Plowing	1.7	1.7	1.7
Extra travel of team in turning, etc...	1.5	1.2	0.7
Snatch team	..	1.5	1.5
Wages of man dumping	..	..	0.8
Total, cts. per cu. yd.	5.5	6.4	7.0
Size of load hauled, cu. yds.	1/5	¼	4/10

A snatch team is usually used with No. 2 wheelers, and in short-haul work there is usually a dump man also.

In easy soils, I have had one snatch team assist in loading 300 cu. yds. per day, so that this item may be less than above estimated; and under the same conditions another ½ ct. per cu. yd. or more may be saved in wages of men loading and dumping. There are usually two men required to load a No 3 wheeler, which accounts for the higher cost of this item in the No. 3 column.

The cost of wheeler work, based upon the foregoing data, is as follows:

Rule V.—To a fixed cost of 5½ *cts. per cu. yd. for No.* 1 *wheelers, or* 6½ *cts. for No.* 2 *wheelers, or* 7 *cts. for No.* 3 *wheelers, add the following per cu. yd. per* 100 *ft. of "lead":* 2¾ *cts. for No.* 1 *wheelers; or* 2⅕ *cts. for No.* 2 *wheelers; or* 1⅜ *cts. for No.* 3 *wheelers.*

The cost of foreman's wages and repair of wheelers will add about 1 ct. more per cu. yd.

If the "lead" is 50 ft., and No. 1 wheelers are used, the cost is 5½ cts. + (½ × 2¾ cts.), or 6⅞ cts. (practically 7 cts.) per cu. yd., exclusive of foreman's wages.

Cost by Elevating Graders.—An elevating grader consists essentially of a four-wheeled truck provided with a plow which casts its furrow upon an endless belt, which elevates the material and deposits it in wagons as fast as they are driven under the belt. For successful operation there must be few boulders or roots to stop the plow of the machine; and there must be considerable room in which to turn the machine, and manoeuver the teams going and coming. The machine is adapted to loading wagons on road work, but is especially suitable for reservoir work and the like. The machine is used in prairie soils for digging ditches and conveying the material directly into the road, but the material must afterward be leveled with a leveling scraper or road machine; and it would seem better practice to use the road scraper entirely for this class of grading without resort to the elevating grader at all. Claims have been made that 1,000 cu. yds. in 10 hours are loaded by the grader. The author, however, has never seen a daily average of more than 500 cu. yds. place measure loaded by a grader operating in easy soil.

A grader costs about $1,000, and is hauled either by 10 or 12 horses or by a 25-HP. traction engine, the latter being the more economical in the long run. It requires 2 men to operate the grader, and, where horses are used, 2 or 3 men to drive the horses. Where a traction engine is used, 2 men operate the grader, 1 engineman operates the traction engine, and it is often necessary to keep a team busy part of the time hauling water for the engine, if water is not supplied by gravity or by pumps. The traction engine burns 0.7 ton, or 1,400 lbs., per 10 hrs. To furnish steam there will be required not over 8 lbs. of water per lb. of coal, or 0.7 × 8 = 5.6 tons of water per day. The grader travels about 150 ft. per min. when hauled by an engine, and it takes 1½ mins. to turn around at each end of its run, describing a circle of about 50 ft. diameter in turning. It takes about 15 seconds to load a wagon with ¾ cu. yd. of earth measured in place, when the grader is traveling 150 ft. per minute, so that the

grader travels 40 ft. in loading a ¾-yd. wagon; then it stops for about 15 secs. until the next wagon comes up under the belt. If three-horse patent dump wagons are used—and no other kind should be used with elevating graders—the wagon load is 1¼ cu. yds., and the grader travels about 65 ft. to load a wagon.

I have seen 700 two-horse wagons, holding ¾ cu. yd. each, loaded per 10-hr. day; and, I am informed, that with good management and an easy soil, 700 wagons, holding more than 1 cu. yd. each, can be loaded per 10-hr. day. With three-horse wagons the average 10-hr. day's output on the Chicago Drainage Canal was 500 cu. yds. of top soil.

Mr. N. Adelbert Brown, C. E., of Rochester, informs me that an elevating grader was used by Thomas Holihan, in grading streets at Canandaigua, N. Y. The streets were 60 to 75 ft. wide between property lines, and 36 ft. between curbs. A traction engine was used to haul the grader, and there was no trouble in turning the engine and grader between the walk lines, which was easily within 50 ft. of space. "The efficiency of the machine was not tested fully, due to a lack of teams; but, when teams were available, 50 wagon loads, of 1½ cu. yds. each, were readily loaded in an hour. The machine was satisfactory in stone and gravel roads and stiff clay, but in light sand in some cases refused to elevate." This latter is true, however, of all elevating graders in any dry sand that will not turn a furrow.

Fred. T. Ley & Co., of Springfield, Mass., informs me that elevating graders were used by them on electric railway work in Central New York State, both with traction engines and with horses. They averaged 400 to 500 cu. yds. loaded into wagons per grader per day.

No matter how short the lead, a team hauling earth from a grader must perform a large percentage of waste labor following the grader, and this is equivalent to adding about 400 ft. to the "lead." If 3 horses and a driver are worth $4.50 a day, and the load is 1¼ cu. yds., the cost of hauling is 0.6 ct. per cu. yd. per 100 ft. of haul; so that the waste distance traveled (400 ft. lead) adds 2½ cts. per cu. yd. to the cost. With wages of single horses at $1, and men at

$1.50, the fixed cost is as follows, with an output of 500 cu. yds. per 10 hrs.:

	Per cu. yd.
Lost team time (400 ft. added to "lead")	2.5 cts.
10 horses on grader and 4 men	3.5 "
5 men on dump spreading	1.5 "
Plant rental, say $7.50 per day	1.5 "
Total	9.0 "

The rule is:

Rule VI.—To a fixed cost of 9 *cts. add* $^6/_{10}$ *ct. per cu. yd. per* 100 *ft. of lead.*

It will take 6 three-horse wagons to handle the 500 cu. yds. per day where the lead is 500 ft.

It is necessary to spread the earth on the dump to prevent stalling of the dump wagons, but by using a leveling scraper the cost of this item can be reduced.

A traction-engine outfit will reduce the cost of operating the grader somewhat below the above given figures, thus:

	Per day.
⅔ ton coal, at $3	$2.00
1 engineman	3.00
2 grader operators	5.00
Rental of engine	5.00
Total, 500 cu. yds., at 3 cts.	$15.00

This 3 cts. per cu. yd., it will be seen, is 0.5 ct. less than where 10 horses and 4 men operate the grader.

If it is necessary to pump water by hand and haul it far for the traction engine, the cost may easily be increased ½ ct. per cu. yd., or more.

Steam Shovel Data.—The size of a steam shovel is usually denoted by the capacity of the dipper in cubic yards and the weight of the whole machine in tons; both should be given, for in a hard material a smaller dipper is used than in soft material when working with the same steam shovel. The following are some of the standard sizes:

Weight, tons	35	45	55	65	75	90
Dipper, cu. yds.	1¼	1½	1¾	2	2½	3
Coal in 10 hrs., tons..	¾	1	1¼	1½	2	2¼
Water in 10 hrs., gals.	1,500	2,000	2,500	3,000	4,000	4,500

The price of shovels is approximately $130 per ton.

A shovel of any size is so designed that, when digging in average earth, it can average at least 3 dipperfulls per minute, when the dipper arm swings only 90°. Shovels are built to run on standard gage track, and in operating a shovel it is customary to use rails in 5-ft. lengths, so that the shovel cuts 5 ft. into a face before it is shifted ahead. The time required to shift ahead may average as low as 3 mins., and should never average more than 5 mins., but on poorly managed work I have often seen 10 mins. consumed in shifting the shovel ahead.

"Traction shovels" weighing 26 tons, or less, may be had, and they do not require rails to run upon, but are provided with broad-tired traction wheels.

The width of the cut or "swath" excavated by a shovel varies from 18 ft. for the smallest shovels to 40 ft. for the largest. The height of the face of the cut is usually 15 to 30 ft. In tough material the face of the cut should not be higher than the dipper can reach, that is, 14 to 20 ft. Too high a face in treacherous, sliding material is to be avoided, for the shovel may be buried by a slide.

The height of the face of the cut has a marked influence upon the output of a shovel. If the face is only 6 ft. high and 18 ft. wide, there are only 4 cu. yds. per lineal foot of cut, or 20 cu. yds. for every 5 lin, ft. of cut. A 1-yd. shovel would excavate this in, say, 10 mins.; then, if 5 mins. were spent moving forward for the next "bite," there would be 15 mins. required to excavate 20 cu. yds., and one-third of the time would be spent in shifting the shovel. Shallow cuts are expensive not only on this account, but because a full dipper can not be averaged when the height of the face of the cut becomes much less than one and a half or two times the depth of the bucket.

In addition to the lost time of shifting the shovel, there is more or less lost time switching cars up to the shovel. On

"thorough cut" work this lost time of switching is greater than on "side cut" work. A "thorough cut" is practically a huge trench, in which the shovel is working at the face, so that only one or two cars can come up on the track alongside of the shovel, the car track being in the bottom of the cut. This method of attack should be avoided wherever possible. In "side cut" work a full train of cars can come alongside the shovel, one car being loaded after another until the train is loaded.

There are frequently conditions that make it cheaper in the end to use wagons instead of cars for hauling the earth away. In such cases never use a large dipper, for so much earth will spill over the sides of the wagon as to block the road and delay the movement of the wagons, even when a snatch team is used. A 1½-yd. bucket is as large as should be used for loading wagons.

Hauling With Dinkeys.—The ordinary "contractor's locomotive," or "dinkey," travels on a track of 3-ft. gage. The size of dinkey commonly used weighs 8 short tons, and is listed as having a tractive pull of 2,900 lbs. on a level track. Whether the actual tractive capacity is exactly 2,900 I do not know; but it must be approximately that, for any locomotive can exert a pull of 25% of the weight on its driving wheels even on clean rails. The loads that a dinkey can pull, however, are much over-estimated in catalogues, due to too low rolling resistances assumed for cars. It is said in some of the catalogues that the resistance to traction is 6½ lbs. per short ton. This rate applies only to the best of standard gage railway tracks with heavy rails, well ballasted, and with heavy wheel loads. On a contractor's narrow gage, light rail track, the resistance to traction is probably not much less than 40 lbs. per ton, and where the cars are loaded it is doubtless more, due to the dirt on the rails. At any rate, the only careful tests of which I have any knowledge are given in my book, "Earthwork and Its Cost," page 80, where it will be found that nine cars drawn in trains at 4½ miles an hour showed from 26 to 66 lbs. resistance per ton on a level track; the 26 lbs. was only for very well lubricated cars drawn in trains of 20 cars. Short trains (2 to 4 cars) showed higher resistances than long

trains, doubtless due to the greater effect of irregularities in the track, which are more or less counterbalanced in long trains. These same tests show that it requires almost twice as great a pull to start a car as to keep it in motion.

The resistance due to gravity is 20 lbs. per short ton per 1% of grade; but, of course, the tractive power of a locomotive falls off 20 lbs. for every ton of its own weight for each 1% of grade.

Based upon these data, and upon the assumption that the resistance to traction is 40 lbs. per short ton, an 8-ton dinkey is capable of hauling the following loads, including the weight of the cars:

	Total Tons.
Level Track	70
1% grade	46
2% "	33
3% "	26
4% "	21
5% "	17
6% "	14
8% "	10

Note: On a poor track not even as great loads as the above can be hauled.

Due to the accidents that frequently occur from the breaking in two of trains on steep grades, and from the running away of engines, it is advisable to avoid using grades of more than 6%.

When heavily loaded, a dinkey travels 5 miles per hr. on a straight track; but when lightly loaded, or on a down grade, it may run 9 miles an hour.

The following are the average struck measure capacities of the dump cars made by one firm (variations of weight of several hundred pounds occur, according to the make):

Capacity, cu. yds. ..	1	1½	2	2½	3
Weight, lbs.	1,700	2,000	2,300	2,800	3,500

A car seldom averages its struck capacity of earth measured "in place," even when the car is heaped full with a shovel; for not only are there vacant places in the

corners of the car, but the loose earth is 20% to 30% more bulky than earth "in place."

The number of dinkeys required to keep a shovel busy can be estimated from the data given. On short hauls (1,000 ft. or less) one very often sees only one dinkey serving a 1½-yd. shovel. In such cases the dinkey is not heavily loaded, so that it can run fast, and by having enough men to dump a train of 6 cars in 2 or 3 mins., a fairly good daily output of the shovel can be secured.

In dumping the cars, estimate on the basis of one 3-yd. car dumped by each man in 1½ to 2 mins. The men work in groups of 2 or 3 in dumping the cars, and enough men are usually provided on the dump to dump a train in 3 mins.

When two or more dinkeys are serving one shovel, and long trains (12 cars) are being used, it would seem that very little lost shovel time would occur due to switching in an empty train; but, even under favorable conditions, I find that 1½ to 2 mins. per train are lost in switching. This is another reason why a shovel served by only one dinkey makes so good a showing on short-haul work. Still another reason is that at the time the shovel is shifting forward, the dinkey can often make its round trip; and on shallow face work this shifting of the shovel occurs frequently.

The method of using a hoisting engine and cable to move the cars is quite common in railroad work, where the hauls are short, say 1,000 ft. or less. The track is laid on a rather steep grade, at least 3% from the pit to the dump, and the cars coast down by gravity usually in trains of 4 cars holding about 2 cu. yds. each. The hoisting engines pull the cars back with a wire rope. A team of horses will have all it can do to pull a train of 4 such cars even on a slight down grade to the dump. As a matter of fact, a team that is working steadily can not be counted on to pull more than two cars holding 3 cu. yds. each, on a level track of the kind ordinarily used in contract work.

The 3-ft. gage track commonly used is laid with rails weighing 16 to 40 lbs. per yard of single rail. A 30 or 35-lb. rail makes a track that is not easily kinked under the loads, even when ties are spaced 4 ft. centers. A 6 × 6-in.

tie, 5 ft. long, is the best size. I have tried 4 × 4-in. ties, but they are easily split by the spikes, and are not of much value after being used once; whereas the 6 × 6-in. ties can be laid 4 to 6 times. After the rails and ties are delivered, and the roadway graded, such a track can be laid for $100 per mile, or $2 per 100 ft., when wages are 15 cts. per hr. And the track can be torn up and loaded on wagons for $1 per 100 ft.; there being 1 ton of 30-lb. rails, and 375 ft. B. M. of 6 × 6-in. × 5-ft. ties per 100 ft. of track.

In railroad work it is usually necessary to build a trestle through which the cars are dumped in making the embankment. The trestles usually consist of two posts per bent, the posts being of round timber, capped with a squared stick, and sway braced with round timber saplings. Under Piling and Timberwork the reader will find data on the cost of trestlework.

Summary of the Cost of Steam Shovel Work.—As above stated, shovels are so designed that about 3 dipperfuls can be averaged per minute when actually loading cars; but I find that even with well arranged tracks, and a good high face, the necessary delays of shifting the shovel ahead, switching the trains, moving the shovel back to start a new swath, etc., keep the shovel idle about half the time. Occasionally, under exceptionally favorable conditions, a shovel may average 6 or 6½ hrs. of actual shoveling per 10-hr. day.

The size of the dippers, as listed in catalogues, often refers to dippers heaped full of loose earth. I find that the actual "place measure" averages about 30% less than the listed capacity of a dipper, for not every dipper goes out full, and even if it does the earth is not as compact in the dipper as in place.

On the basis of 3 dippers loaded per minute of actual work, we have the following for dippers of different sizes:

Dipper.		Output in Cubic Yards. Steady Shoveling.	
Nominal. Yds.	Actual (average). Yds.	10 hrs.	5 hrs.
1	.7	1,260	630
1¼	1.	1,800	900
2	1.4	2,520	1,260
2½	1.7	3,060	1,530

We see that where the shovel is actually shoveling 5 hrs. out of the 10 (and this is a good average), a 1-yd. dipper will load 630 cu. yds.; a 1½-yd. dipper, 900 cu. yds.; a 2½-yd. dipper, 1,530 cu. yds. These are not merely theoretical outputs, for I have monthly output records that show these averages for each 10-hr. shift. However, the track arrangement must be such that cars are promptly supplied to the shovel, if any such average as 900 cu. yds. per day per 1½-yd. dipper is to be maintained.

Taking the 1½-yd. dipper as the common size, we may say that in "average earth," with cars promptly supplied, 900 cu. yds. are a fair 10-hr. day's work; but if only one dinkey is used, the lost time may easily be increased to such an extent that 650 cu. yds. become a good day's work in "average earth." In hardpan, or exceedingly tough clay, the output of a shovel may fall to about half the output in "average earth"; that is, 450 cu. yds. per 10-hr. day with a 1½-yd. shovel.

The size of shovel to select for any given work depends upon the yardage of earth in each cut—not upon the total yardage in the contract. Use a small 26-ton traction shovel, with 1-yd. dipper for small cuts, where moves from one cut to another will be frequent. Use a 55 to 65-ton shovel with 1½ to 2½-yd. dipper where cuts are heavy, and moves not very frequent. Use a 75 to 90-ton shovel, with 2½ to 3½-yd. dipper, on heavy cuts, where moves are infrequent. Of course a heavy shovel with a small dipper is necessary in hardpan and very tough material.

The cost of operating a 55-ton shovel is ordinarily as follows:

1 foreman	$5.00
1 engineman	4.00
1 craneman	3.50
1 fireman	2.00
6 pitmen, at $1.50	9.00
1 night watchman	2.50
2 enginemen on 2 dinkeys, at $3	6.00
2 trainmen, at $2	4.00
4 dumpmen, at $1.50	6.00

10 trackmen, at $1.50	$15.00
1 pumpman	2.50
4 blacksmiths, carpenters, etc., on repairs	12.00
2 water boys, at $1	2.00
Supplies for repairs	6.00
Coal, 1.3 tons for 1 shovel, at $4	5.20
Coal, 0.6 ton for 2 dinkeys, at $4	2.40
Coal, 0.2 ton for 1 pump to supply water	0.80
Oil and waste	1.00
15% interest and depreciation on $15,000 plant, distributed over 150 days worked per year	15.00
Total per 10-hr. day	$103.90

The above data are based upon actual records given in the author's books, "Rock Excavation" and "Earthwork and Its Cost."

The 10 trackmen are engaged in grading for new tracks, track-shifting, etc. The 4 dumpmen must be increased to 8 dumpmen where the material is not dumped through trestles, and where long trains are hauled. The 6 pitmen keep the bottom of the pit level for the shovel track, shift the sections of shovel track, clean away the spilled material from the car track, etc. Under favorable conditions the number of trackmen may be very much reduced; for example in heavy cuts requiring infrequent shifting of tracks, and where tracks are well laid.

If the daily output of the 1½-yd. shovel is 900 cu. yds., the cost is slightly less than 12 cts. per cu. yd. If tough material and unfavorable conditions reduce the output to 600 cu. yds., the cost is 17 cts. per cu. yd. If the hauls are very long, and if grades are not favorable, more than 2 dinkeys may be required. The number can be estimated from the data previously given.

References.—For further data on the cost of earth excavation, the reader is referred to the author's book, "Earthwork and Its Cost," where he will find not only fuller discussions and data relating to the common methods of excavation, but methods and costs of dredging, hydraulick-

ing, excavating with power scrapers, conveying on inclines, etc.

Other data on earthwork will be found in this "Handbook of Cost Data," under the sections on Roads, Sewers, Waterworks, and Miscellanies, for which consult the index under Earthwork.

SECTION III.

COST OF ROCK EXCAVATION, QUARRYING AND CRUSHING.

Weight and Voids.—Civil engineers commonly measure rock excavation by the cubic yard in place before loosening, whereas mining engineers generally use the ton of 2,000 pounds as the unit of rock and ore measurement. In view of this fact it would be well were the specific gravity of the rock given by every engineer who publishes data on any particular kind of rock excavation or mining. Then, too, it often happens that broken rock is purchased by the ton even for civil engineering work, or by the cord of loosely piled rubble for architectural work, thus emphasizing the importance of stating not only the specific gravity but the percentage of voids.

The specific gravity of any material is the quotient found by dividing its weight by the weight of an equal bulk of water. Water, therefore, has a specific gravity of 1; a cubic foot of any substance like granite, having a specific gravity of 2.65, weighs 2.65 times as much as a cubic foot of water. A cubic foot of water weighs 62.355 lbs., or practically 62.4 lbs.; hence a cubic foot of solid granite weighs, $62.4 \times 2.65 = 165.3$ lbs.

When any rock is crushed or broken into fragments of tolerably uniform size it increases in bulk, and is found to have 35% to 55% voids or inter-spaces, depending upon the uniformity of the fragments and their angularity. Rounded fragments, like pebbles, pack more closely together than sharp-edged or angular fragments. A tumbler full of bird shot has about 36% voids, and it is possible to hand-pack marbles of uniform size so that the voids are only 26%. Obviously, if small fragments of stone are mixed with large fragments, the voids are reduced. Pit sand ordinarily has 35 to 40% voids. Hard broken stone from a rock crusher

has about 35% voids if all sizes are mixed and slightly shaken down in a box; whereas, if it is screened into several sizes, each size has about 45 to 48% voids.

A soft and friable rock like shale breaks into fragments having a great range in size, from large chunks down to dust; and, as a consequence, such soft broken rocks have a much lower percentage of voids than the tougher rocks.

The following table shows the swelling of rock upon breaking:

Voids.	30%	35%	40%	45%	50%	55%
Cu. yds. broken rock from 1 cu. yd. solid rock......	1.43	1.54	1.67	1.82	2.00	2.22

Hard rock when blasted out in large chunks and thrown into cars or skips may ordinarily be assumed to have from 40 to 45% voids, hence 1 cu. yd. of hard solid rock ordinarily makes 1.67 to 1.82 cu. yds. of broken or crushed rock.

Tables of specific gravity and weight of different kinds of rock will be found in the section on Concrete.

Measurement of Rock.—Rock excavation is commonly measured in place before loosening, and paid for by the cubic yard of actual excavation; but, in sewer work and in tunnel work, if the contractor excavates beyond certain "neat lines" shown in the blue-prints, no payment is made, unless the specifications explicitly provide for payment for excavation beyond these "neat lines." In trench work, for example, a contractor often has to excavate from 6 to 18 ins. below the grade shown in the blue-print, because it costs less to do so than to work too close to the grade and afterward break off projecting knobs with a bull-point or otherwise. The same is true of shallow excavation, or skimming work, in road construction and the like.

In examining specifications care should also be taken to note whether mention is made of rock slips or falls; for it often happens that after blasting to the neat lines a huge slide of rock occurs, possibly filling the entire excavation. Who is to stand the cost of removing this slide? If it is prescribed that the contractor shall, then he should study the dip of the rock and its character with this question of sliding in mind.

A perch of masonry is commonly taken as being 25 cu. ft. (or nearly 1 cu. yd.), but the original perch was a wall 12 ins. high, 18 ins. wide, and a rod (16½ ft.) long, making 24¾ cu. ft. In certain localities the "perch" is taken as being only 22 cu. ft., but in most places in this country a perch is only 16½ cu. ft. These facts the contractor should know, for he must often deal with quarrymen who will not sell rock by the cubic yard.

In some localities stone for building is sold by the cord. Sedimentary rock quarried in slabs that are corded up carefully by hand may have 30% or less voids, which makes it evident that a contractor in buying rock by the cord should be careful to prescribe that it be packed closely and not dumped in piles helter skelter before measurement. In buying rock by the "cord" there is another precaution to be taken, and that is to specify how many cubic feet constitute a cord. A cord of wood is $4 \times 4 \times 8 = 128$ cu. ft., but a "cord" of stone is often $1 \times 4 \times 8 = 32$ cu. ft. Rock is often purchased by the ton of 2,000 lbs.; but to avoid lawsuits it is wise to define the word "ton" in any written or verbal contract, for a ton means 2,240 lbs. in some localities.

If crushed stone for macadam or ballast is purchased by the cubic yard measured loose, the precaution of stating where the measurement is to be made should always be taken. I have made measurements of wagon loads of broken stone after loading from chutes at the bins, and again after traveling for half a mile or more. A surprising shaking down, or settlement, always takes place, ordinarily making a reduction in volume of 10%.

There is another caution to be taken in examining specifications and in buying stone for concrete. Note whether or not the specification requires that the largest permissible stone shall pass *in every direction* through a ring of, say, 2½ ins. diameter. I have italicized the words "in every direction" because few engineers realize and few contractors stop to think that this virtually means the use of a much smaller opening in the screen than the one specified, in this case smaller than 2½ ins. In screening stone in a rotary screen, long narrow fragments will drop through a

2½-in. hole, yet many of these fragments will not pass "in every direction" through a 2½-in. hole. On this account, small though the matter seems, I once had more than 1,000 cu. yds. of stone rejected by an inspector who found that he could not pass through a ring some of the long fragments when laid crosswise.

There are two ways of designating the sizes of stone after screening. One is to designate the stone according to the diameter of the screen hole through which it has passed; in this case stone that has passed a 2½-in. hole is called "two and a half inch stone." Another, and very common way, is to take the diameter of the screen hole through which the stone did not pass, add it to the diameter of the screen hole through which the stone did pass, divide this sum by two, and call this average diameter the size of the stone. Suppose, for example, that a stone crusher were provided with a rotary screen having three sections of perforated metal, the holes in the first section being ¾-in. diameter, the holes in the second section 1½-in., and in the third section 2½-in. Then the average size of the stone that passes the ¾-in. holes is ⅜-in. stone (assuming it to run from dust to ¾-in.) The average size of the stone that passes the 1½-in. holes but does not pass the ¾-in. holes, is (1½ + ¾) ÷ 2, or 1⅛-in., and it may be called 1⅛-in. stone, In like manner the stone between 1½-in. and 2½-in. may be called 2-in. stone. This rule is not followed strictly by the manufacturers of crushed stone, so it is always necessary to inquire exactly what they mean when they speak of stone of a certain size. Thus the Rockland Lake Trap Co. have the following schedule of commercial sizes:

Diameter of holes in screen, inches......	4¼	3¼	2¼	1 1/16	⅝
Commercial sizes of stone, inches........	3½	2½	1½	¾	½

Therefore, when "2½-inch stone" is ordered from this company, they ship a product that ranges from 2¼ ins. to 3¼ ins. in size—indeed, some of the stone fragments are even larger than 3¼ ins. in certain directions, for, as above stated, a long, narrow stone may pass through a screen.

Kinds of Hand Drills.—Drilling holes in rock by hand may be effected in three ways: (1) By a rotary drill or auger; (2) by a churn-drill; (3) by a hammer-drill, or

"jumper" drill, struck with a hammer. A rock auger operated by hand is used only in very soft rock or coal.

A churn-drill, as its name implies, is raised and allowed to drop, or is hurled against the rock. For shallow holes of small diameter it is necessary to give a churn-drill additional weight, which is done by welding a ball of wrought iron to the center of the drill shank, making a ball-drill. A ball-drill is usually provided with a cutting bit at each end, and is operated by one man. For deep drilling, that is, for holes more than about 2½ or 3 ft. deep, an ordinary churn-drill is used, operated by one man for shallow work, two men for deeper work, and three or even four men for very deep holes where the weight of metal becomes considerable.

The churn-drill in the hands of a skilled driller is the most effective type of hand drill for vertical holes; and a little theory is not without its practical value in seeking the reason for the effectiveness of the churn-drill. Much of the energy of the blow of a hammer is lost in the form of heat at the head of the drill. This loss does not occur with the churn-drill. It takes some skill to start a hole with a ball-drill and to keep it plumb; but the time spent in acquiring this skill is repaid many times over if quarry operations with hand drills are to be moderately extensive.

The effect of the size of the hole upon the speed of drilling appears never to have been carefully determined. One authority says that to double the diameter of the hole decreases the speed of drilling by one-half. Another authority thinks that doubling the diameter divides the speed by four. According to the first authority, if a man could drill 12 ft. of 1-in. hole in a shift, he could drill only 6 ft. of 2-in. hole in a shift. According to the second authority, only 3 ft. of 2-in. hole could be drilled per shift.

Cost of Hammer Drilling.—The diameter of the hole, the angle at which the hole is driven and the presence or absence of water in the hole, all affect the cost of drilling by hand. The method of drilling with hammer-drills or with churn-drills is also an important factor in the cost. Obviously the character of the rock is the most important factor; but unfortunately very few reliable records of cost

of drilling in different kinds of rock are to be found. From some observations on hammer drilling with a 1½-in. starting bit I have found that where one man is holding the drill vertically and two men are striking, the rate of drilling a 6-ft. hole is as follows:

	Ft. in 10 hrs.	Cost per ft., cts.
Granite	7	75
Trap (basalt)	11	48
Limestone	16	33

The cost is based upon a wage rate of $1.75 per 9-hr. day per man; and does not include the cost of sharpening drills, which may be taken at 5 to 8 cts. per ft. more.

I have found that a man drilling plug and feather holes in granite, each hole being ⅝-in. diam. by 2½ ins. deep, will average one hole in 5 mins., including the time of cleaning out holes, the driller striking about 200 blows in drilling the hole. No water is used in drilling these shallow holes, for the dust is readily and quickly cleaned out with a little wooden spoon. In 8 hrs. of steady work about 100 holes can be drilled, which is about 21 ft. of ⅝-in. hole. But in plug and feather work part of the time is spent in selecting rock, driving the plugs, etc., so that 50 or 60 holes drilled and plugged and feathered are generally counted a fair day's work.

I am indebted to Mr. John B. Hobson for the following data of hammer drilling in a British Columbia mine: Rock was augite diorite and firm red porphyry; starting bit, 1¾ ins.; finishing bit, 1¼ ins.; ⅞-in. steel; holes, 6 ft. deep; 8-lb. hammer. Two miners (one holding drill and one striking) averaged 14.8 ft. per 10-hr. shift. With wages at $2 a day the cost was nearly 28 cts. per ft. of hole.

Mr. Frank Nicholson states that in mining chalcopyrite in magnesian limestone at St. Genevieve, Mo., a day's work for a striker and a holder was 12 ft. of hole drilled. The drills had 1¼-in. starting bits, ⅞-in. octagon steel being used.

In excavating hard porphyry for the rock-fill dam at Otay, Cal., Mr. W. S. Russell states that a good day's work for

three men drilling (one holding and two striking) was 6 to 8 ft. of hole, costing about 80 cts. per ft. of hole drilled. The holes were drilled 20 ft. deep vertically and sprung. This was an unusual depth of hole for hammer drilling, and accounts for the high cost per foot. It shows also how uneconomic is hammer drilling in deep vertical holes compared with churn drilling.

In driving a small (3 × 4½-ft.) tunnel through tough sandstone one driller averaged 4 to 5 holes, each 1½ ft. deep, per 8-hr. shift, using ⅞-in. bit for the starter; and, upon cleaning up, the advance was 1 ft. per shift for one man. Each hole was charged with half a stick of 75% dynamite.

Cost of Churn Drilling.—I am indebted to Mr. W. M. Douglass, of the firm of Douglass Bros., contractors, for the following data on drilling with churn-drills, for railroad work in western Ohio. Three drillers were used for putting down the first 18 ft. of hole in blue sandstone the first day (10 hrs.), and four men were used for putting down the last 12 ft. of hole, so that it required 70 hrs. of labor at 15 cts. per hr., or $10.50, for a 30-ft. hole, making the cost 35 cts. per ft. In brown sandstone it required 70 to 80 hrs. labor to put down 30 ft. The drill holes were 2¾ ins. at top and 1½ ins. at bottom. Drilling with steam drills in this same stone, holes 20 ft. deep, cost 12 cts. per ft., including everything except interest, depreciation and drill sharpening. The cost of hand drilling agrees very closely with my own records of similar work in Pennsylvania.

Trautwine gives the following rates of drilling 3-ft. vertical holes, starting with a 1¾-in. bit, one man drilling with a churn-drill, shift 10 hrs. long:

Solid quartz	4	ft. in 10 hrs.
Tough hornblend	6	" " " "
Granite or gneiss	7.5	" " " "
Limestone	8.5	" " " "
Sandstone	9.5	" " " "

It should be observed that the holes in this case are shallow (3 ft.), and the diameter (1¾ ins.) is large for such shallow holes, indicating that Trautwine's data applied to rock excavation where black powder was used.

Sizes of Air Drills.—The size of an air drill is denoted by the inner diameter of its air or steam cylinder; thus a 3¼-in. air drill is one having a cylinder 3¼ ins. diam.

The smallest sizes, 2¼-in. drill, is called a "baby drill," or a one-man drill—the latter name being given to the drill because it can readily be moved about and set up by one man. For narrow work in mines the baby drill is adapted. It is also used for drilling plug and feather holes, and might often be used profitably for shallow cuts and trenches. The most commonly used sizes for general contract work, tunneling and mining are the 3⅛-in. and the 3¼-in. drills. The drill is churned back and forth in the hole by compressed air or steam power, and after each stroke it is mechanically turned a fraction of a circle. The drill is fed forward by hand, a crank at the end of a feed-screw being used for this purpose. A longer drill is inserted every 2 ft. in depth of hole, for 2 ft. is the limit of feed of the ordinary feed screw used.

Test of Air Consumption at the Rose Deep Mine.—A 6-hr. run at the Rose Deep Mine, South Africa, showed the following results for 31 drills: The compressed air averaged 70 lbs. per sq. in. and each 3¼-in. drill consumed 81 cu. ft. of free air per minute, including all leakage of pipes (there was less leakage than is common in mines). Each drill required 43 lbs. of coal per hour, to supply this compressed air; and each 3.4 lbs. of coal developed 1 HP. per hour, by the indicator on the steam engine, evaporating 6.74 lbs. of water from 212° F. The average horse-power of the compressor engine was 12.7 I. HP. per drill; but all the drillers were trying to make a record, and accomplished in 6 hrs. an amount of drilling that ordinarily took 8 hrs. The power plant was a vertical King-Reidler Compound Steam and Double Stage Air Compressor, with two boilers of the horizontal return tubular type.

Tables of Air Consumption in Catalogues.—Table I. is given in the catalogue of one of the well-known drill manufacturers, and is said to be based upon actual tests of single drills running continuously without stops for changing bits, etc.

TABLE I.—Cubic Feet of Free Air per Minute Required to Run a One-Drill Plant.

Gauge Pressure.	Diameter of Drill Cylinder.												
	2″	2¼″	2½″	2¾″	3″	3⅛″	3 3/16″	3¼″	3½″	3⅝″	4¾″	5″	5½″
60	50	60	68	82	90	95	97	100	108	113	130	150	164
70	56	68	77	93	102	108	110	113	124	129	147	170	181
80	63	76	86	104	114	120	123	127	131	143	164	190	207
90	70	84	95	115	126	133	136	141	152	159	182	210	230
100	77	92	104	126	138	146	149	154	166	174	199	240	252

When more than one drill is to be supplied from the same air compressor the manufacturers advise multiplying the quantities given in Table I. by the factors given in Table II.

TABLE II.

Number of drills..	1	2	5	10	15	20	30	40	70
Multiply value in Table I. by	1	1.8	4.1	7.1	9.5	11.7	15.8	21.4	33.2

Tables similar to these are given by other manufacturers. In answer to letters of inquiry I have been informed that such tables are "based upon experience in a large number of mines."

The actual drilling time, that is, the time when the drill is actually striking blows, is seldom over 70%, and often not more than 40% of the length of the shift. Knowing the conditions of work, the reader will be able (with the aid of data given subsequently) to predict approximately the per cent. of actual drilling time. Then, if there are more than, say, 10 drills, he can multiply the air consumption of one drill (when actually drilling) by the percentage of drilling time in the shift, and the product will be the average air consumption of each drill. If there are less than about 10 drills it will not be safe to figure so closely, because the fewer the drills operated from one compressor, the more likely is it that all or nearly all of them will be using air at the same time. The larger the number of drills, on the other hand, the more certain it is that some will be changing bits while others are drilling, and thus draw a steady, average amount of air from the compressor.

Steam Consumption.—When steam is piped directly

from the boiler into a drill, practically the same number of cubic feet of steam are consumed as of cubic feet of compressed air. We may assume that a cubic foot of steam will do practically the same work in a drill as a cubic foot of compressed air at the same pressure, because neither the steam nor the air acts to any great extent expansively in a drill cylinder, due to the late cut off. This being so, 0.21 lb. of steam is equivalent to 6 cu. ft. of free air, or 1 lb. of steam is equivalent to nearly 30 cu. ft. of free air, or 1 cu. ft. of free air is equivalent to 0.035 lbs. steam—all at the same pressure of 75 lbs. per sq. in. If a drill consumes at the rate of 100 cu. ft. of free air per min., it will consume 6,000 cu. ft. of free air in an hour. If it were using steam in its cylinder instead of air (at 75 lbs. pressure), it would, therefore, consume $6{,}000 \times 0.035 = 210$ lbs. of steam (at 75 lbs. pressure) in an hour.

When coal is burned under a boiler a large percentage of its heat passes up the chimney in the gases and is lost; and in addition to this loss the boiler itself radiates heat constantly. The greater part of the loss occurs in the heat that goes up the chimney. In large, well designed boilers, properly protected by asbestos or similar covering, the coal burned will develop steam to about 80% of the full heat value of the fuel; the efficiency of the boiler and furnace is then 80%. In locomotive boilers, where forced draft is used, firing not of the best and boiler exposed to moving air, the efficiency is often as low as 45%. The efficiency of a good boiler of moderate size (100 HP.), well housed, is ordinarily about 75%. A small (20 HP.) boiler exposed to the wind has an efficiency of about 60% when not forced. If a small boiler is used to run one drill, the boiler must always have up enough steam to keep the drill running at nearly full capacity; but when the drill is stopped, during the changing of bits, moving, etc., there is a waste of steam, because the period of stoppage is not long enough to permit the fireman to make any material change in the firing and in the draft.

When a ¾-in. drill is operated by steam from a small boiler, about 600 lbs. of coal are ordinarily required per 10-hr. shift. But if a number of drills are supplied from a

large, well lagged boiler, through steam pipes that are also lagged with asbestos covering, it is possible to cut down the coal consumption to 300 lbs. or less per drill per 10 hrs.

Gasoline Air Compressors.—Where not more than three or four drills are to be operated, probably no power can equal compressed air generated by gasoline. One pint of gasoline per hour per brake horse-power (B. HP.) of gasoline engine may be counted upon as the average consumption. It will require about 12 HP. to compress air for each drill (3¼-in. size); hence 12 pints, or 1½ gals. of gasoline will be required per hour per drill while actually drilling. Since gasoline air compressors are self-regulating, when the drill is not using air very little gasoline is burned by the gasoline engine driving the compressor. If the drill is actually drilling two-thirds of the working shift, we may safely count upon using about 1 gal. of gasoline per hour of shift per drill, or 8 gals. per shift 8 hrs. long. If gasoline is worth 15 cts. per gal., delivered at the engine, one drill consumes only $1.20 worth of gasoline per shift of 8 hrs. A gasoline compressor possesses other very important economic advantages over a small steam-driven plant. First, there is the saving in wages of firemen; for, once started, a gasoline engine runs itself. Second, there is the saving in hauling or pumping of water and the hauling of fuel. Third, the cost of gasoline is often less than the cost of coal for operating a small plant.

Percentage of Lost Time in Drilling.—In operating machines of any kind the percentage of lost time is a factor that should receive the most careful consideration. The most serious loss of time in machine drilling is the time lost in changing bits and pumping out the hole; for, with a 2-ft. feed screw (which is the ordinary length), a new drill must be inserted for every 2 ft. of hole drilled. It takes from 4 to 16 minutes to drill 2 ft. of hole, counting the actual time that the drill is striking, and it ordinarily takes from 2 to 5 minutes to change bits and pump out the hole. I have often timed the work, however, where 9 minutes were spent in drilling, followed by 9 minutes lost by lazy drillers in changing bits. Counting no other time losses, then, half the avail-

able time was lost in the operation of changing bits. When shallow holes (6 ft. or less), are to be drilled, the drill steel is light, and there is often little or no sludge pumping to be done. In such cases it is possible for the driller and his helper to change bits in 1 minute, or even less when they are rushing the work. So far as the changing of bits is concerned, men should be made to work with a vim. When men have to exercise their muscles incessantly for 8 or 10 hours there is reason in taking a slow, steady gait, but in machine work, muscular exercise is intermittent, and should be vigorous.

Next in importance to the time lost in changing bits is the time lost in shifting the machine from hole to hole. To move a tripod from one hole to the next and set up again ready to drill seldom consumes less than 7 minutes, even when the two men are working rapidly, when the distance to move is short, and when the rock floor is level and soft. When, however, the rock floor is irregular and hard, requiring the vigorous use of gad and pick, not only in making holes for the tripod leg points to rest in, but requiring, also, some little time in squaring up a face for the bit to strike upon, the two men may consume from 30 to 45 minutes, shifting the machine and setting up, if they work deliberately. In such cases it is advisable to have laborers working ahead of the drillers preparing the face of the rock, leveling the site of the hole, removing loose rock, etc. One can see clearly what a great saving in time may thereby be effected; yet, this simple expedient is seldom adopted; but the driller and his helper are usually left to themselves in preparing the ground for each new set up. Excluding the time required to change bits for the new hole, we may say that two men can ordinarily make a new set up with a tripod in 12 to 15 minutes, if they work rapidly.

Rule for Estimating Feet Drilled per Shift.—We are now possessed of sufficient data to enable us to formulate a rule whereby the number of feet drilled per shift, under given conditions, may be predicted. I will not go into the method that I used in deducing the following rule, which is strictly correct, for the method is one of simple arithmetic. The rule is:

To find the number of feet of hole drilled per shift divide the total number of working minutes in the shift by the sum of the following quantities: The number of minutes of actual drilling required to drill one foot of hole, plus the average number of minutes required to change bits divided by the length of the feed screw in feet, plus the average number of minutes required to shift the machine from hole to hole divided by the depth of the hole in feet.

Suppose, for example, the shift is 10 hrs. long, that is, 600 mins.; that it requires 5 mins. to drill 1 ft. of the rock; that it requires 4 mins. to change bits and clean hole; that the feed screw is 2 ft. long; that the machine can be shifted from hole to hole in 16 mins.; and that each hole is 8 ft. deep. Then according to the rule we have: The number of feet of hole per shift is $600 \div (5 + \frac{4}{2} + \frac{16}{8})$, which is equivalent to $600 \div 9$, or $66\frac{2}{3}$ ft. drilled per 10-hr. shift.

For those who can use simple algebraic formulas the above rule is much more compactly expressed in the following formula:

$$N = \frac{S}{r + \frac{m}{f} + \frac{s}{D}}$$

N = number of feet drilled per shift.

S = length of working time of shift in minutes = 600 for a 10-hr. shift when no time is lost by blasts, breakdowns, etc.

r = number of minutes of actual drilling required to drill 1 ft. of the rock.

m = number of minutes required to crank up, change drills, pump out hole and crank down.

m = 3 to 4 mins. ordinarily.

f = length of feed screw, in ft., ranging from $1\frac{1}{4}$ ft. in "baby" drills to $2\frac{1}{2}$ ft. in largest drills, but ordinarily 2 ft.

s = number of minutes required to shift machine from one hole to the next, including the time of chipping and starting the new hole, but not including the time of crank-

ing up and cranking down. S ranges from 5 mins. for very rapid shifting on level rock, to 40 mins. for very slow shifting on irregular rock.

D = depth of hole in ft.

Even a casual study of the foregoing formula, or rule, must impress the practical man with the importance of the lost time elements in machine drilling; consequently of the value of timing the operations of changing bits and moving machines when the men do not know that they are being timed. Another feature that stands out strikingly is the reduced output of a drill working in a shallow hole. Let the reader solve a few problems, assuming first an average depth of hole of 16 ft. and finally an average depth of only 2 ft. (such as occurs often in the skimming work in road building), and he will never make the blunder of the contractor who bid the same price for rock excavation on the 2-ft. deepening of the Erie Canal as had been bid for the 36-ft. excavation on the Chicago Canal.

If we assume that the shift is 10-hrs. long; that the rate of drilling is 1 ft. in 5 mins.; that it takes 4 mins. to change bits and pump out the hole at each change of bits; that the feed screw is 2 ft. long; and that it takes 15 mins. to shift from one hole to the next; by applying the rule we obtain the following results:

Depth of hole, ft.	1	2	3	5	10	15	20
Feet drilled in 10 hrs.	27	41	50	60	70	75	80

When drillers are lazy they may readily consume 8 mins. in changing bits and pumping out the hole each time. With all conditions the same as before, excepting that 8 mins. are consumed in changing bits, we have the following results:

Depth of hole, ft.	1	2	3	5	10	15	20
Feet drilled in 10 hrs.	25	36	43	50	57	60	62

It will be seen that in deep hole drilling 20% decreased efficiency results from just a little laziness in changing bits, under the conditions assumed; and in softer rocks the percentage of decreased efficiency is much greater. Where the holes are shallow the time involved in shifting from one hole to the next becomes an important factor. Assuming

that the conditions are the same as in the first instance, except that 30 mins. are consumed in shifting from one hole to the next, then we have the following results:

Depth of hole, ft.	1	2	3	5	10	15	20
Feet drilled in 10 hrs.	16	27	35	46	60	67	70

Rates of Drilling in Different Rocks.—Unfortunately no published record exists showing rates of drilling in different kinds of rock with given air or steam pressures and given sizes of drill bits. Such scattering records as are to be found merely give the feet of hole drilled per shift. From data obtained by observation I have compiled the following table for drilling with 3⅛-in. machines using air or steam at 70 lbs. pressure, starting bit about 2¾ ins. and finishing bit about 1½ ins.:

	Time to drill 1 ft.
Soft sandstones, limestones, etc.	3 mins.
Medium, ditto	4 "
Hard granites, hard sandstones, etc.	5 "
Very hard traps, granites, etc.	6 to 8 "
Very soft shales, and other rocks that make sludge rapidly and when a water jet is not used	8 to 10 "

That the inexperienced reader may have a good general conception of what constitutes a day's work under ordinary conditions the following summary may be of benefit: In drilling vertical holes, with the drill on a tripod, the holes being from 10 to 20 ft. deep, shift 10 hrs. long, I have found that in the hard "granite" of the Adirondack Mts., N. Y., 48 ft. is a fair 10-hr. day's work. In the granites of Maine and Massachusetts 45 to 50 ft. is a day's work. In New York City, where the rock is mica schist, deep holes are drilled at the rate of 60 to 70 ft. per 10-hr. shift by men willing to work, but 40 to 50 is nearer the average of union drillers. In the very hard trap rock of the Hudson River 40 ft. is considered a fair day's work. In the soft red sandstone of northern New Jersey 90 ft. are readily drilled per day wherever the rock is not so seamy as to cause lost time by the sticking of the bit; in fact, I have records showing

110 ft. per 10-hr. shift in this rock. In the hard limestone near Rochester my records show about 70 ft. per 10-hr. shift, In the limestone on the Chicago Drainage Canal 70 to 80 ft. was a 10-hr. day's work. In the hard syenite of Douglass Island, in open pit work, and where it is difficult to make set-ups, 36 ft. is now the average per 10-hr. day. In the limestone near Windmill Pt., Ontario, 3⅝-in. drills average 75 ft. a day (holes 18 ft. deep); 2¾-in. drills, 60 ft. a day, and "baby" drills, 37 ft. a day.

The foregoing examples all apply to comparatively deep vertical holes, in open excavation. In tunnel work there is no reason why a drill should not do about the same work per shift, were there no delays in timbering, mucking, waiting for gases to clear, etc. Such delays, however, often reduce the drill footage very much.

Cost of Sharpening Bits.—One blacksmith (with a helper) will sharpen about 140 bits a day, and under ordinary conditions will keep 5 to 7 drills supplied with sharp bits. On average rock a bit must be sharpened for every 2 ft. of hole; in very soft rock a bit for every 4 ft., and in very hard rock a bit for every 1½ ft. of hole.

Cost of Drill Repairs.—Mr. Thomas Dennis, agent of the Adventure Consolidated Copper Co., Hancock, Mich., has kindly furnished the following data of the average monthly cost of keeping a drill in repair:

Supplies for repairs	$1.31
Machinist labor	8.45
Blacksmith labor	1.60
Total repair charge per month	$11.36

The number of drills in the shop at any one time is about 15 per cent. of the total number. This low cost is based upon work where a large number of drills are used and well handled by the users.

I am indebted to Mr. Josiah Bond, mining engineer, for the statement that the cost of repairs averages 50 cts. per drill per shift in mines where a few drills are operated and renewal parts purchased from the manufacturers. In open cut work my experience is that 75 cts. per drill per shift is

a fair allowance for renewals and repairs. In the gold mines of South Africa, where each drill works two shifts per day, the cost of drill repairs is $300 per drill per year; while the first cost of a 3¼-in. drill with bar is $185, according to a recent report of the Government Mine Inspector.

Cost of Operating Drills.—When operating a single (3¼-in.) drill supplied by steam from a small portable boiler, I find the cost is usually as follows for a 10-hr. shift:

1 drill runner	$3.00
1 drill helper	1.75
1 fireman	2.00
660 lbs. of coal (0.3 ton at $3)	.90
Water, if hauled, say	.75
Hauling and sharpening 30 bits (incl. new steel) at 4 cts.	1.20
Repairs to drill and hose renewals	.75
Total per 10 hrs.	$10.35

The foregoing is merely an example, based, however, upon several different jobs; but in each case the accessibility of a blacksmith, the nearness to water, the price of coal delivered at the boiler, etc., must be determined before an accurate estimate can be made. If 4 drills, for example, are to be operated from the same boiler, the fuel bill will be somewhat reduced even if the pipes are not covered with asbestos, and of course the wages of the fireman will be distributed over 4 drills. It will then pay to have a blacksmith at hand. If 10 or more drills are run by steam from a central boiler, and if the main pipes are lagged, the fuel should not much exceed 300 lbs. per drill per 10-hr. shift. By the rules previously given a fairly close estimate can be made of the number of feet of hole that each drill should average. If 60 ft., for example, are to be a fair day's work in limestone or sandstone, we have $10.35 ÷ 60 = 17 cts. per ft. as the cost, exclusive of superintendence, plant installation and plant rental.

If a central compressor or steam plant supplies power for, say, 15 drills, we may estimate the cost of operating each drill as follows:

1 drill runner	$3.00
1 drill helper	1.75
1-15 fireman at $2.25	.15
1-15 compressor man at $3	.20
300 lbs. coal (water nominal) at $3 ton	.45
Sharpening bits, 30 at 3 cts.	.90
Repairs to drill, hose, etc.	.75
Total for 60 ft. of hole at 12 cts.	$7.20

If the cost of each drill and 1-15 part of the compressor plant is $350, and 30 per cent. of this is assumed as a fair allowance for annual plant rental, we have $105 to charge up against each drill for "rental," or about 50 cts. per shift if 200 shifts are worked each year, or about 1 ct. per ft. of hole drilled.

In my book "Rock Excavation—Methods and Cost" will be found detailed data on the cost of drilling blast-holes with well-drillers of the "Cyclone" type. The holes were 3 ins. diam. × 24 ft. deep in sandstone and cost 12½ cts. per ft. to drill.

Cost of Loading by Hand.—Where a laborer has merely to pick up and cast one-man stone into a jaw crusher, I have had men average 34 cu. yds. of loose stone handled per man per 10-hr. shift, which is equivalent to about 20 cu. yds. of solid rock. This, I believe, marks the maximum that may be done, day in and day out, by a good worker, where the stone has scarcely to be lifted off the floor to toss it into the jaws. Every stone, however, was handled and not shoved or slid into the crusher.

On the Chicago Canal the average output per man per 10-hr. shift was about 7 cu. yds. loaded into dump cars, and this included some sledging. The average per man loading into the low skips used on the cableways, involving very little sledging, was about 10 cu. yds. of solid rock per man per 10-hr. shift. The best day's record was 16.6 cu. yds. per man loading into skips. In loading cars about 5 men out of the force of 36 loaders were kept busy sledging the rock; but with the cableways not only was it easier to roll large rocks into the skips (or "scale pans"), but very large rocks

were lifted with grab hooks and chains and carried to the dump without sledging.

In loading wagons with stone readily lifted by one man, the wagon having high sides, I have found that a man will readily average 10 cu. yds. solid, which is equivalent to 17 cu. yds. loose measure per day of 10 hrs. The same man will throw the stone out of the wagon twice as fast as he will load it, and this does not mean dumping the wagon, but handling each stone separately. In loading a wagon having a stone-rack, and no sides, two men, passing stone up to the driver, who cords the stone on the rack, will load 1 cu. yd. solid stone in 13 mins. when working rapidly, but this is too high an average to be maintained steadily for a full day. A driver will unload 1 cu. yd. solid (or 1.7 cu. yd. loose) from such a stone-rack, by rolling the stone off, in 7 mins. if he hurries, but he may take 20 mins. if he loafs. A man will readily load a wheelbarrow with stone already sledged and ready for the crusher at the rate of 12 cu. yds. solid (or 21 cu. yds. loose) in 10 hrs.

Cost of Handling Crushed Stone.—In handling stone after it has been crushed to 2½-in. size, or smaller, a shovel is used, and the output of a man depends very largely upon whether he is shoveling stone that lies upon smooth boards or upon the ground. I have often had 6 good shovelers unload a canal boat holding 120 cu. yds. loose measure of crushed trap rock (2-in. size) in 9 hrs., but after breaking through to the floor the shoveling was comparatively easy; this is 20 cu. yds. loose (or 12 cu. yds. solid) per man per day shoveled into skips. In shoveling from flat cars into wagons the same rate can be attained, but in shoveling from a hopper-bottom car, where there is at no time a smooth floor along which to force the shovel, an output of 14 cu. yds. loose measure (or 8 cu. yds. solid) is a fair 10-hr. day's work. In shoveling broken stone off the ground into wagons it is not safe to count upon much more than 12 cu. yds. loose measure (or 7 cu. yds. solid) per man per 10 hrs. A careful manager will, if possible, provide a smooth platform, preferably faced with sheet iron, upon which to dump any stone that is to be re-handled by shovelers. Small stone, ¾-in. or less in diameter, is easily pene-

trated by a shovel and need not be dumped upon a platform. A clamshell bucket operated by a locomotive crane, is doubtless the most economic method of loading broken stone from cars or stock piles, where the quantity to be handled warrants the installation.

Cost of Handling with a Derrick.—If crushed stone must be handled with a derrick, as in unloading boats and cars, use the data given in the section on Roads.

Cost of Loading with Steam Shovels.—A contractor who has never had experience in handling hard rock with steam shovels is almost certain to overestimate the probable output of a shovel loading rock. This is due very largely to the common tendency to think of all rock as being a material that differs only to moderate degree in hardness. On the Chicago Drainage Canal, two 55-ton shovels, each working two 10-hr. shifts a day for four months, averaged 296 cu. yds. per shovel per shift of solid rock (limestone) loaded into cars, although it is stated that one day one of the shovels loaded 600 cu. yds. of rock in 10 hrs. The limestone on the Chicago Canal did not break up into small pieces upon blasting (a condition that is essential to economic steam shovel work in rock), but it came out in large chunks, much of which had to be lifted with chains, instead of being scooped up by the dipper. When each separate rock must be "chained out" in this way, a steam shovel is really no better than a derrick, and is, in fact, not so good.

On a large contract near New York City, where the rock is a tough mica-schist that breaks out in large chunks even with close spacing of holes, a 65-ton shovel with a 2¼-cu. yd. dipper averaged for several weeks about 280 cu. yds. of solid rock loaded in cars. Part of this rock was loaded with the dipper and part was chained.

On the Jerome Park Reservoir excavation in New York City the rock is also a tough mica-schist that blasts out in slabs even with heavy blasting. I am informed by Mr. R. C. Hunt, manager for Mr. John B. McDonald, contractor, that their 70-ton shovels loaded only 300 cu. yds. of solid rock per 10-hr. shift. Mr. Hunt says:

"This was in the gneiss rock (mica-schist) of this vicinity.

The fibrous nature of Manhattan and adjacent rocks causes it to break in such large and awkward shapes that the shovel cannot do itself justice. I therefore abandoned the use of shovels in the rock cuts and find that I can handle the rock with derricks more economically."

In thorough cut work on the Wabash Railroad, one 42-ton shovel loaded 240 cu. yds. of sandstone (solid measure) into dump cars in 10 hrs., as an average of a year's work; but about 10 per cent. of the working time was lost in breakdowns, etc.

In shale, or any friable rock that breaks up into pieces which readily enter the dipper, the output of a steam shovel is far greater than in hard rock such as we have been citing. Through the kindness of Mr. George Nauman, assistant engineer, Pennsylvania Railroad, I am able to give the output of several shovels working more than a year, in shale near Enola, Pa. Each shovel worked two 10-hr. shifts per day, six days in the week. In cut No. 1 there were nearly 2,000,000 cu. yds., of which 85 per cent. was rock. Of this rock a little was very hard limestone, some was blue shale nearly as hard, and most of it was red shale, somewhat softer. Excluding the first two months, the average output of each shovel per month of double-shift work was nearly 31,000 cu. yds., equivalent to 15,500 cu. yds. single-shift work. There were, on an average, four shovels at work, averaging 60 tons weight per shovel. The best month's output was 47,300 cu. yds. per shovel in August, 1903, and the poorest month (after work was well started) was 20,800 cu. yds. per shovel in February, 1904, working double shifts.

Cost of Handling in Carts and Wagons.—Since a cubic yard of loose broken stone weighs about as much as a cubic yard of earth measured in place; and since, ordinarily, 1 cu. yd. of solid rock becomes 1.7 cu. yds. when broken, we may say that a team will haul about 60 per cent. as many cubic yards of solid rock per day as of earth. In other words, if the roads are such that 1 cu. yd. of packed (not loose) earth would make a fair wagon load for two horses, then 0.6 cu. yd. of solid rock would be a fair load. On page 76 the sizes of loads of earth that teams can haul

are discussed, and it is only necessary to multiply the earth load as given there by 6-10 (or 60%) to find the equivalent load of solid rock.

Open-Cut Excavation.—This includes all rock excavation in open cuts (except trenches), where no special care is used to quarry the stone in certain sizes for masonry, but where explosives are used freely to break out the rock in sizes that can be handled with the appliances available.

Spacing Holes in Open-Cut Excavation.—A common rule is to place the row of vertical drill holes a distance back from the face equal to the depth of the drill hole, and to place the drill holes a distance apart in the row equal to their depth. Another rule is to place the row of holes back from the face a distance equal to three-fourths their depth, and the same distance apart in the row. In stratified rock of medium hardness these rules may be followed in making the first experiments, but they will lead to serious error if applied to dense granitic rocks. In the limestone on the Chicago Canal, not much of which was loaded with steam shovels, the holes were usually 12 ft. deep and placed in rows about 8 ft. back of the face and 8 ft. apart. These holes were charged with 40 per cent. dynamite. In a railway cut through sandstone the holes were 20 ft. deep, 18 ft. back from the face and 14 ft. apart in the row. These holes were "sprung" three times, and each hole charged with 200 lbs. of black powder. In granite quarried for rubble for dam work, I have had to place the holes 4½ to 5 ft. back of the face and the same distance apart, the holes being 12 ft. deep, about 2 lbs. of 60 per cent. dynamite being charged in each hole. On railway work in the Rocky Mountains about the same spacing was found necessary in granitic rock that was to be broken up into chunks that a steam shovel could handle. In pit mining at the Treadwell Mine, Alaska, the holes are drilled 12 ft. deep, in rows 2½ ft. apart, the holes being 6 ft. apart in each row and staggered. This requires drilling 1.7 ft. of hole per cu yd.

It is obviously impossible to lay down any hard and fast rule for the spacing of drill holes. In stratified rock that is friable, and in traps that are full of natural joints and seams, it is often possible to space the holes a distance

apart somewhat greater than their depth, and still break the rock to comparatively small sizes upon blasting. In tough granite, gneiss, syenite and in trap where joints are few and far between, the holes may have to be spaced 3 to 8 ft. apart, regardless of their depth, for with wider spacing the blocks of stone thrown down by blasting will be too large to handle with ordinary appliances. The mica-schist, or gneiss, of Manhattan Island is a good example of rock that requires close spacing of holes regardless of depth. I have seen holes in it 20 ft. deep and only 4 ft. apart.

The effect of spacing of holes upon the cost of excavation is best shown by tabulation of the feet of hole drilled per cubic yard excavated, as shown in Table III.:

TABLE III.

Distance apart of holes, ft.	1	1.5	2	2.5	3	3.5	4	4.5	5
Cu. yds. per ft. of hole	.04	.08	.15	.23	.33	.45	.59	.75	.93
Ft. of hole per cu. yd.	27.0	12.0	6.8	4.3	3.0	2.2	1.7	1.33	1.08
Distance apart of holes, ft.	6	7	8	9	10	12	14	16	18
Cu. yds. per ft. of hole	1.33	1.80	2.37	3.00	3.70	5.32	7.25	9.52	12.05
Ft. of hole per cu. yd.	.75	.56	.42	.33	.27	.19	.14	.11	.08

Since in shallow excavations the holes can seldom be much further apart than 1 to 1½ times their depth, we see that the cost of drilling per cubic yard increases very rapidly the shallower the excavation. Thus an excavation 2 ft. deep, with holes 2 ft. apart, requires 4.3 ft. of drill hole per cubic yard, as against 0.42 ft. of hole per cu. yd. in a deeper excavation where drill holes are 8 ft. apart. Failure to consider this fact ruined one contractor on the Erie Canal deepening, where rock excavation was only 2 ft. deep. Furthermore, the cost of drilling a foot of hole is much increased where frequent shifting of the drill tripod is necessary.

By observing carefully the appearance of rocks in different localities it is possible in a short time to become tolerably proficient in the art of estimating the probable distance apart that holes must be drilled for the best effect

with given charges of given kind of explosive; and with this end in view a young man should avail himself of every opportunity of studying prevailing practice in spacing drill holes in different localities.

Cost of Excavating Sandstone and Shale.—In excavating shales and sandstones of the coal measures of Pennsylvania, Ohio, Virginia, etc., I find that holes are usually 20 to 24 ft. deep, and spaced 12 to 18 ft. apart. On an average we may say that for every cubic yard of solid rock there is 0.1 lin. ft. of drill hole, when cuts are very wide, covering large areas of ground; but in thorough cuts for railroads it is not safe to count upon much less than 0.2 ft. of drill hole per cu. yd. The holes are almost invariably sprung with 40 per cent. dynamite and then charged with black powder. As low as 1/50 lb. of dynamite per cu. yd. may be used for springing holes in shale, and as high as ½ lb. per cu. yd. in sandstone that is to be very heavily loaded. I should put the average at 1/20 lb. of dynamite per cu. yd. of shale, and 1/10 lb. per cu. yd. of sandstone. A very common charge is 8 kegs (200 lbs.) of black powder per hole, or about 1 lb. per cu. yd. in side cuts, and 1½ to 2 lbs. per cu. yd. in thorough cuts, although as high as 3 lbs. per cu. yd. have been used in thorough cuts in sandstone where special effort was made to break up the rock to small sizes for steam shovel work. The drilling of the deep holes costs not far from 40 cts. per lin. ft. where drilling is done by hand with wages at 15 cts. an hour, and it may be as low as 12 cts. a lin. ft. if well drillers are used. Soda powder costs about 5 cts. per lb., and 40 per cent. dynamite 12 cts. per lb. We have, therefore, the following:

	Cts. per cu. yd.
Drilling 1/10 ft. to 2/10 ft. at 40 cts.	4.0 to 8.0
Dynamite 1/20 lb. to 1/10 lb.	0.6 to 1.2
Powder, 1 lb. to 2 lbs.	5.0 to 10.0
Total for loosening the rock	9.6 to 19.2

The rock is commonly loaded with steam shovels, and it is not safe to count upon more than 500 cu. yds. of shale, or 250 cu. yds. of sandstone per shovel per 10-hr. shift.

Summary.—The two cost items that the inexperienced man should seek first to inform himself upon, are: (1) The number of feet of hole drilled per cubic yard in different kinds of rock; and (2) the number of pounds of explosive required per cu. yd. under varying conditions. In Table IV. I have given a summary of these items as applying to open cut work discussed in this book; the table does not apply to trenching, tunneling or other narrow work. Two examples are given for sandstones and two for shales, such as occur in the coal measures of Pennsylvania. In a thorough cut on railroad work, we have conditions that approach trench work, requiring more feet of hole and more powder than in open side cuts; hence the differences between Examples 5 and 6, 7, and 8. It will be observed that the large amount of drilling in Example 2 is due to the shallowness of the face or lift, and in Examples 9 to 12 it is due to the toughness of the rock.

I shall greatly appreciate further contributions of similar data from my readers, for use in future editions. The greater the number of records, such as those in this table, the better will readers be able to judge the range and the average for each class of rock.

TABLE IV.

	Per Cubic Yard.					
Example.	Depth of Lift. Feet.	Feet of Hole.	Lbs. of Black Powder.	Lbs. of Dynamite.	Grade of Dynamite.	Kind of Rock.
1....	12	.40	....	.75	40%	Limestone, Chicago Canal.
2....	6	1.00	....	.7	40%	" for crushing.
3....	20	....	....	.37	50%	" for cement.
4....	15	.43	....	.26	50%	" (holes sprung).
5....	20	.1	1.0	.1	40%	Sandstone, side cut.
6....	20	.2	2.0	.2	40%	" thorough cut.
7....	24	.08	.7	.03	40%	Shale, soft, side cut.
8....	24	.20	1.5	.10	40%	" hard, thorough cut.
9....	16	1.36	....	.20	60%	Granite, for rubble.
10....	12	1.33	....	.60	40%	Gneiss, New York City.
11....	14	.63	....	.50	40%	" "
12....	12	1.7	....	.67	40%	Syenite, Treadwell mine.
13....	12½	.32	....	.44	52%	Magnetic iron ore.
14....	14	.35	....	.20	75%	Trap, seamy.
15....	16	1.0	....	.70	40%	" massive.

Trenching in Rock.—This is a subject upon which practically nothing has ever been written. In consequence there is probably no class of rock work that is so often mismanaged; and, as a further consequence of the prevailing ignorance, engineers' estimates of cost are often far too low and occasionally as far too high. In city specifications for sewer trenching in rock it is customary to pay the contractor only for rock excavated within specified "neat lines." If he excavates beyond the "neat lines" he does so at his own expense. In sewer work the most common practice is to specify that payment will be made for a trench 12 ins. wider than the outside diameter of the sewer pipe, and 6 ins. deeper than the bottom of the pipe when the pipe is laid to grade. The most rational specification that I have seen for general use in rock trenching is as follows: "All trenches in rock excavation will be estimated 2 ft. wider than the external diameter of the pipe and 6 ins. below the sewer grade."

Different rocks vary greatly in the way the sides and bottom shear off upon blasting. The sides of trenches in soft rocks can be cut off clean when the blast holes are properly loaded; but tough granites, traps, etc., leave jagged walls, generally involving excavation beyond the "neat lines" specified.

In excavating thin bedded, horzontally stratified rocks the drill holes seldom need to go much, if any, below the neat lines; that is, 6 ins. below the bottom of the pipe. But in excavating thick bedded and tough limestones and the like, it is generally necessary to drill 12 ins. below the bottom of the pipe. In tough granites, traps, etc., it is often necessary to drill at least 18 ins. below grade in order to leave no knobs or projections after blasting that would require breaking off with bull points and sledges. Obviously the shallower the trench the greater is the importance of making due allowance for this extra drilling.

The common practice in placing drill holes is to put down holes in pairs, one hole on each side of the proposed trench; and, if the trench is wide, one or more holes are drilled between these two side holes. However, it is not always necessary to drill the two holes (one on each side); but in narrow trench work, such as for a 12-in. water pipe,

one hole in the middle of the trench will usually prove sufficient if it is made of large enough diameter to hold a heavy charge of dynamite. For example, in trenching for a 12-in. waterpipe in New Jersey trap rock, holes were drilled in the center of the trench, 6 ft. deep, and 2 ft. apart. The result was a great saving in the cost of drilling per cubic yard.

Cost of Drilling and Blasting.—Next to tunneling there is no class of rock excavation requiring so much drilling per cubic yard as does trench excavation. In granites, if shallow holes are drilled by hand, the holes are frequently spaced not more than 1½ ft. apart. If in a very narrow trench 1½ ft. wide two holes are drilled in a row, one on each side of the trench, and if the rows are 1½ ft. apart, we have two holes drilled in a square 1½ ft. on a side; that is, for every 2¼ cu. ft. of rock we must drill 2 ft. of hole, or 24 ft. of drill hole per cu. yd. If the cost of drilling is 25 cts. a foot, we have $\$0.25 \times 24 = \$6$ per cu. yd. as the cost of drilling alone. It is seldom, however, that such narrow trenching is done. Trenches for small pipes are usually 2½ to 3 ft. wide; two holes are usually drilled in a row, and rows are usually about 3 ft. apart. A trench 3 ft. wide with two holes in a row, and rows 3 ft. apart, requires 6 ft. of drilling per cubic yard. With drilling costing 50 cts. per ft., as it often does where hand drills are used in granite, the cost is then $3 per cu. yd. for drilling alone. Unless the job is too small to pay for installing a plant, hand drilling should never be used in trench work, because the drilling forms such a very large part of the cost.

In a trench 6 ft. wide in hard New Jersey trap rock three holes were drilled in a row; one close to each side and one in the middle, and the rows were 3 ft. apart, thus requiring 4½ ft. of drill hole per cu. yd. of excavation. The drilling was done with steam drills at a cost of 30 cts. per lin. ft., for the holes were only 4½ ft. deep, the rock was hard, and the men slow, about 35 ft. being the day's work per drill. The contractor had to drill 1½ ft. below grade in this rock to insure having no projecting knobs of rock. While it cost $1.35 per cu. yd. to drill the 3½ ft. for which payment was made, to this must be added nearly 30%, or

$0.40 per cu. yd., to cover the cost of drilling the extra 1 ft. for which no payment was received, making the total cost of drilling $1.75 per cu. yd. of pay material. About 2 lbs. of 40% dynamite were charged in each hole, making about 2.6 lbs of dynamite per cu. yd. of pay material. The explosives thus added another $0.40 per cu. yd., making a total of $2.15 per cu. yd. for drilling and blasting.

In the same trap rock, where the trench was 8 ft. wide and 12 ft. deep, there were three holes in a row and rows were 4 ft. apart, requiring 2.53 ft. of hole per cu. yd. of pay excavation, plus 0.21 ft. of hole per cu. yd. of pay material to cover the cost of drilling the last 1 ft. of hole below the "neat line." Each drill averaged 45 ft. of hole in 10 hrs., and the cost was 23 cts. per ft. of hole; hence $\$0.23 \times 2.74 = \$0.63$ per cu. yd. was the cost of drilling. About 4 lbs. of 40% dynamite were charged in each hole, or 1.1 lbs. per cu. yd. of pay material, making the total cost 80 cts. per cu. yd. for drilling and blasting. A comparison of this cost of 80 cts. with the $2.15 above given brings out strikingly the fact that each problem of trench work must be considered in detail by itself.

In a city where the contractor must fire comparatively small shots in order to avoid accidents to buildings and suits for damages arising from "disturbing the peace," it is seldom possible to space the holes more than 3 or at most 4 ft. apart. In trenching in soft sandstone in Newark, N. J., where the trench was 14 ft. wide and 10 ft. deep, there were five holes in a row (the distance between holes being 3½ ft.) and rows were 4 ft. apart, making 2.4 ft. of hole per cu. yd. Each hole was charged with 4.12 lbs. of 40% dynamite, making practically 1 lb. per cu. yd. About half the dynamite was charged at the bottom of each hole, then tamping was put in, and the other half was charged up to about 2½ ft. below the mouth of the hole. Each steam drill averaged 90 ft. of hole per 10 hrs., making the cost of drilling 10 cts. per ft. of hole, or 24 cts. per cu. yd. Including the cost of dynamite and the placing of timbers over each blast, the cost of drilling and blasting was 40 cts. per cu. yd. This is probably as low a cost for breaking rock in a wide trench as can be counted upon under favorable conditions. In this rock there was no necessity of drilling below grade.

I am indebted to Mr. F. I. Winslow for the following data on trench work in Boston, Mass.: For house sewer trenches, contractors are allowed 3 ft. width, and trenches for water pipe (16 ins. or less), 2½ ft. width. The rock is granite, and the drill holes are usually 3 ft. apart drilled along the center of the trench, but staggered a little off center. On small jobs hammer drills are used, one man holding and two striking. For a hole 10 ft. deep the starting bit is 2½ ins. and the finishing bit is 1¼ ins. diam. A drilling gang of three men averages 8 to 10 ft. of hole in 10 hrs., although in very soft rock 20 ft. may be drilled in 10 hrs. In a trench 10 ft. deep, the rock is usually excavated in two 5-ft. benches, but some contractors drill the full 10 ft. and take it out in one 10-ft. bench. Forcite containing 75% nitroglycerin is commonly used, ½ to 3 sticks being charged in a hole. Force account records for granite trenching, on jobs of less than 100 cu. yds. each, show that the average cost during the past 15 years has been $3.80 per cu. yd., including excavating and piling up the rock alongside the trench. The wages paid hand-drillers were $1.75 per 10-hr. day; and to laborers, $1.40 per day.

I am indebted to the Harrison Construction Co., of Newark, N. J., for the following information: In a sandstone trench about 6 ft. wide the holes were spaced about 3 ft. apart, thus requiring 4½ ft. of hole per cu. yd. In seamy rock, shallow holes 4 to 6 ft. deep were drilled, and from 2 to 3 sticks of 50% dynamite were charged, each stick being 1½ × 8 ins. This is equivalent to 0.55 lb. per cu. yd. Where the rock was solid, the holes were drilled 8 to 10 ft. deep and the dynamite charge doubled.

The cost of throwing rock out of shallow trenches or of loading it into buckets to be raised by the engine of a derrick, a locomotive crane or a cableway, is somewhat greater than the cost of handling rock in open cuts. A fair day's work for one man is 6 cu. yds. of rock handled, when there is little sledging; but the output may be only 4 cu. yds. where there is a large amount of sledging to be done.

If cableways or derricks are used for hoisting the rock, bear in mind that they will be idle most of time, for the drilling limits the output. With a given number of drills

to a cableway, estimate the number of cubic yards of rock that the drills will break per day and divide this yardage into the daily cost of operating the cableway. Thus, in a trench 6 ft. wide, if the holes are 3 ft. apart, each cubic yard of rock requires 4½ ft. of hole, and each drill will break 13⅓ cu. yds. per day where 60 ft. of hole is a day's work. With four drills per cableway the daily output is $4 \times 13\frac{1}{3} = 53\frac{1}{3}$ cu. yds. The cableway would be capable of handling several times this output were it not limited by the drilling. Notwithstanding that all this seems self evident, I have known more than one contractor to overlook the fact that the cost of handling rock from trenches is very much greater than in open cuts where holes are farther apart and where a few drills can keep a cableway busy.

Cost of Quarrying and Crushing Trap.—The following data relate to quarrying New Jersey trap rock and crushing it in gyratory crushers. The quarry face was 12 to 18 ft. high. The output of the following gang was 200 cu. yds. of crushed stone per 10-hr. day, each cubic yard of crusher run product weighing 2,700 lbs., no piece being more than 2 ins. diameter. The weight of a solid cubic yard of this trap was 4,500 lbs., so that the voids in the crushed stone were 40%. Drill holes were spaced about 5 ft. apart.

	Per day.	Per cu. yd.
3 drillers at $2.75	$8.25	$0.041
3 helpers at $1.75	5.25	0.026
10 men barring out and sledging	15.00	0.075
14 men loading carts	21.00	0.105
4 cart horses	6.00	0.030
2 cart drivers	3.00	0.015
2 men dumping carts and feeding crusher	3.00	0.015
1 fireman for drill boiler	2.50	0.013
1 engineman for crusher	3.00	0.015
1 blacksmith	3.00	0.015
1 blacksmith helper	2.00	0.010
1 foreman	5.00	0.025
2 tons coal at $3.50	7.00	0.035
150 lbs. 40% dynamite at 15 cts.	22.50	0.113
Total	$106.50	$0.533

Interest, depreciation and repairs would add about $8 or $10 more per day, or 4 to 5 cts. per cu. yd. There was no earth stripping.

The stone was loaded into one-horse dump carts, the driver taking one cart to the crusher while the other cart was being loaded. The haul was 100 ft. The carts were dumped into an inclined chute feeding into a No. 5 Gates gyratory crusher. The stone was elevated by a bucket elevator and screened. All stone larger than 2-in. was retured through a chute to a small No. 3 Gates crusher to be re-crushed.

I should add that the trap rock was much seamed, so that upon blasting it was broken into tolerably small chunks, so that the cost of sledging was not high considering the small size of the crusher.

Sizes and Weight of Crushed Trap.—Mr. William E. McClintock gives the following data relative to Massachusetts trap rock: The rock weighs 180.7 lbs. per cu. ft. solid, or 4,879 lbs. per cu. yd. solid, being very heavy. The crushed trap of the Mass. Broken Stone Co., at Salem, weighs 2,586 lbs. per cu. yd., and has 47% voids. A rotary screen is used 10 ft. long, 40 ins. diameter, with three sections 3½ ft., 3 ft. and 3 ft. long respectively, having circular holes ½-in., 1½ ins. and 3 ins. diameter. A bin holding 29 cu. yds. was used to measure the ½-in. screenings which were afterward weighed and found to average 2,605 lbs. per cu. yd. A box holding 1 cu. yd. was packed full with wet screenings which weighed only 2,480 lbs. The same box packed full of the same kind of screenings dry was found to hold 2,690 lbs. A bin holding 90 cu. yds. of the 1½-in. stone averaged 2,423 lbs, per cu. yd.; and a bin of the same size full of 3-in. stone, averaged 2,522 lbs. per cu. yd. This 3-in. stone was again measured in cars, and found to average 2,531 lbs. per cu. yd.

To determine the percentages of the different sizes, 19 cu. yds. of broken stone were measured and found to run as follows:

½-in. trap	13.24%
1½-in. trap	23.89%
3-in. trap	62.87%
Total	100.00%

The tailings over 3 ins. in size were re-crushed.

More data on the sizes and weights of broken stone will be found in the sections on Roads and on Concrete. Consult the index under Broken Stone.

Cost of Breaking Stone by Hand.—At Rochester, N. Y., I found that a good 10-hrs. work for a skilled man was 3 cu. yds. of limestone broken to 2-in. sizes, but that 2 cu. yds. were all a beginner could break.

Cost of Crushing at Newton, Mass.—A. F. Noyes, City Engineer of Newton, Mass., gives the following cost data for the year 1891, on four jobs of crushing stone and cobbles for macadam. On jobs A and B the stone was quarried and crushed; on jobs C and D cobblestones were crushed. A 9 × 15-in. Farrel-Marsondon crusher was used, stone being fed in by two laborers. A rotary screen having ½, 1 and 2½-in. openings delivered the stone into bins having four compartments, the last receiving the "tailings" which had failed to pass through the screen. The broken stone was measured in carts as they left the bin, but several cart loads were weighed, giving the following weights per cubic foot of broken stone:

	Size.			
	½-in. lbs.	1-in. lbs.	2½-ins. lbs.	Tailings. lbs.
Greenish trap rock, "A"	95.8	84.3	88.3	91.0
Conglomerate, "B"	101.0	87.7	94.4	....
Cobblestones, "C" and "D"..	102.5	98.0	99.6	....

A one-horse cart held 26 to 28 cu. ft (average 1 cu. yd.) of broken stone; a two-horse cart, 40 to 42 cu. ft., at the crusher.

	Job.			
	A.	B.	C.	D.
Hours run	412	144	101	198
Short tons per hour..........	9.0	11.2	15.7	12.1
Cu. yds. per hour	7.7	8.9	11.8	9.0
Per cent. of tailings	31.8	29.3	17.5	20.5
Per cent. of 2½-in. stone	51.3	51.9	57.0	55.1
Per cent. of 1-in. stone........	10.2	....	....	....
Per cent. of ½-in. stone or dust	6.7	18.8	25.5	23.4

	Job A.	Job B.	Job C.	Job D.
Explosives, coal for drill and repairs	$0.084	$0.018	....	....
Labor steam drilling	0.092	....	....	....
Labor hand drilling	....	0.249	....	....
Sharpening tools	0.069	0.023	....	....
Sledging stone for crusher	0.279	0.420	....	....
Loading carts	0.098	0.127	....	$0.144
Carting to crusher	0.072	0.062	$0.314*	0.098
Feeding crusher	0.053	0.053	0.033	0.065
Engineer of crusher	0.031	0.038	0.029	0.036
Coal for crusher	0.079	0.050	0.047	0.044
Repairs to crusher	0.041	....	....	0.011
Moving portable crusher	....	0.023	....	0.019
Watchman ($1.75 a day)	....	0.053	0.022	0.030
Total cost per cu. yd.	$0.898	$1.116	$0.445	$0.447
Total cost per short ton	0.745	0.885	0.330	0.372

NOTE.—"A" was trap rock; "B" was conglomerate rock; "C" and "D" were trap and granite cobblestones. Common laborers on jobs "A" and "D" were paid $1.75 per 9-hr. day; on jobs "B" and "C," $1.50 per 9-hr. day; two-horse cart and driver, $5 per day; blacksmith, $2.50; engineer on crusher, $2 on job "A," $2.25 on "B," $2.00 on "C," $2.50 on "D"; steam driller received $3, and helper $1.75 a day; foreman, $3 a day. Coal was $5.25 per short ton. Forcite powder 11½ cts. per lb.

Cost of Quarrying and Crushing Quartzite.—Mr. W. G. Kirchoffer gives the following data on the cost of quarrying and crushing quartzite for macadam, in 1903, at Baraboo, Wis. The plant was a municipal plant operated by day labor, and the costs were somewhat higher than under contract work. The crusher was a No. 3 Austin jaw crusher, 12 × 16-in. opening. Three sizes of screen holes in the rotary screen were used: ¾-in., 1¾-in. and 2½-in. The first cost of the plant was as follows, in 1901:

Crusher	$900
Bins	108
Steam drill	218
Small tools	108
	$1,334

*Loading and hauling in wheelbarrows.

The output of the crusher by years has been:

	Year. 1901.	1902.	1903
Total output, cu. yds.	1,920	3,700	4,883
Days worked	47	70	88
Output per day, cu. yds.	41	53	55½

In the year 1901, about 10% of the stone was screened out and thrown away. The wages paid per 10-hr. day were: Laborers, $1.50; quarrymen, $1.75; drill-runner, $2; engineman and engine, $3.50. The stone was measured in wagons built to hold just 1½ cu. yds., by weight, 3,900 lbs., and the following costs for 1903 are based upon wagon measurement of the stone:

	Per cu. yd.
Quarry rent	$0.0207
Labor quarrying, including foreman	0.3200
Labor crushing	0.1980
Tools	0.0148
Dies for crusher	0.0636
Dynamite (60% at 25 cts. per lb.), caps and fuse	0.0910
Rent of engine and wages of engineman	0.0635
Fuel for engine, $4.60 per ton	0.0477
Oil and waste	0.0033
Hauling water and supplies	0.0499
Supplies	0.0137
Superintendent of crusher	0.0476
Depreciation of plant	0.0736
Total	$1.0074

The cost of hauling 2½ miles to the street was 50 cts. per cu. yd., wages of team and driver being $3 a day.

The cost of the macadam pavement, including stone, hauling, grading, spreading stone, claying and rolling, has been a little less than 50 cts. per sq. yd. The macadam was 8 ins. thick at the center and 6 ins. at the gutters, measured after rolling.

Other Data on Crushing.—The size of jaw crushers is commonly denoted by the size of opening through which the stone passes to the jaws. A 9 × 15-in. crusher is one having an opening 9 ins. wide by 15 ins. long; which is the

common size for portable plants. To move such a crusher a few miles from one location to another, set up the bins, etc., preparatory to crushing, costs about $75, according to the author's experience. The main part of this cost consists in tearing down and rebuilding the bins, mounting the rotary screen and adjusting the bucket-elevator. There are several makes of portable bins on wheels now in the market, and with these the cost of moving should be much reduced. A large bin capacity, however, is desirable to "tide over" any irregularities in the hauling and in the operation of the crusher itself. Bins should always be used to save the cost of shoveling the broken stone into wagons.

The gyratory crusher is now largely used on large permanent plants. The following are the sizes of the style "D" Gates gyratory crusher:

Size No.	Diameter at top out to out.	Size of each receiving opening.	Weight of crusher, lbs.	Tons per hr. to 2½-in. size.	HP. for crusher, elevator and screen
1	3 ft. 6 ins.	5 × 18 ins.	5,500	4 to 8	8 to 10
2	3 ft. 10 ins.	6 × 21 ins.	8,000	6 to 12	12 to 15
3	4 ft. 6 ins.	7 × 22 ins.	14,000	10 to 20	20 to 25
4	6 ft. 8 ins.	8 × 27 ins.	21,000	15 to 30	25 to 30
5	7 ft. 10 ins.	10 × 30 ins.	30,000	25 to 40	30 to 40
6	8 ft. 7 ins.	11 × 36 ins.	42,000	30 to 60	40 to 60
7½	10 ft. 8 ins.	14 × 45 ins.	63,000	75 to 125	75 to 125
8	11 ft.	18 × 63 ins.	94,000	125 to 200	100 to 150

The output is given in tons of 2,000 lbs. per hour of rock crushed to pass a 2½-in. ring. A contractor is safe in assuming the smaller outputs given in the table.

Further data on the cost of quarrying and crushing will be found elsewhere in this book in the section on Roads, for which consult the index under Crushing.

References.—In my book, "Rock Excavation: Methods and Cost," further data on the subjects discussed in this section are given; and, in addition, chapters on tunneling, shaft-sinking, dimension-stone quarrying, submarine excavation, channeling, canal excavation, diamond drilling, use of explosives, etc..

In this Hand-Book of Cost Data, the reader will find further information in the sections on Roads, Concrete and Masonry, for which consult the index under Rock Excavation.

SECTION IV.

COST OF ROADS, PAVEMENTS, WALKS, ETC.

Cost of Quarrying and Crushing for Macadam.—The cost of operating a small quarry, and crushing with a portable or semi-portable crusher is obviously much higher than where a large plant is used. For some time to come the greater part of road-metal crushing will be done with small plants, under conditions such as I am about to describe, and at costs not far differing from those that will be given. I have kept itemized records of the cost of quarrying and crushing on a number of different road jobs, and first published (1901) a part of these records in a little book entitled "Economics of Road Construction."

In quarrying limestone, where the face of the quarry was only 5 to 6 ft. high, and where the amount of stripping was small, one steam drill was used. This drill received its steam from the same boiler that supplied the crusher engine. The drill averaged 60 ft. of hole drilled per 10-hr. day, but was poorly handled and frequently laid off for repairs. The cost of quarrying and crushing was as follows:

Quarry.	
1 driller	$2.50
1 helper	1.50
1 man stripping	1.50
4 men quarrying	6.00
1 blacksmith	2.50
⅓ ton coal at $3	1.00
Repairs to drill	.60
Hose, drill steel and interest on plant	.90
24 lbs. dynamite	3.60
Total	$20.10

Crusher.	
1 engineman	$2.50
2 men feeding crusher	3.50
6 men wheeling	9.00
1 bin man	1.50
1 general foreman	3.00
⅓ ton coal at $3	1.00
1 gallon oil	.25
Repairs to crusher	1.00
Repairs to engine and boiler	1.00
Interest on plant	1.00
Total	$23.75

Summary:	Per day.	Per cu. yd.
Quarrying	$20.10	$0.37
Crushing	23.75	0.39
Total for 60 cu. yds	$43.85	$0.76

The "4 men quarrying" barred out and sledged the stone to sizes that would enter a 9 × 16-in. jaw crusher. The "6 men wheeling" delivered the stone in wheelbarrows to the crusher platform, the run plank being never longer than 150 ft. Two men fed the stone into the crusher, and a bin-man helped load the wagons from the bin, and kept tally of the loads. The stone was measured loose in the wagons, and it was found that the average load was 1½ cu. yds., weighing 2,400 lbs. per cu. yd. There were 40 wagon loads, or 60 cu. yds. crushed per 10-hr. day, although on some days as high as 75 cu. yds. were crushed. The stone was screened through a rotary screen, 9 ft. long, having three sizes of openings, ½-in., 1¼-in. and 2½-in. The output was 16% of the smallest size, 24% of the middle size, and 60% of the large size. All tailings over 2½ ins. in size were re-crushed.

It will be noted that the interest on the plant is quite an important item. This is due to the fact that, year in and year out, a quarrying and crushing plant for roadwork seldom averages more than 100 days actually worked per year, and the total charge for interest must be distributed over these 100 days, and not over 300 days as is so commonly and erroneously done. The cost of stripping the earth off the rock is often considerably in excess of the above given cost, and each case must be estimated separately. Quarry rental or royalty is usually not in excess of 5 cts. per cu. yd., and frequently much less. The dynamite used was 40%, and the cost of electric exploders is included in the cost given. Where a higher quarry face is used the cost of drilling and the cost of explosives per cu. yd. is less. Exclusive of quarry rent and heavy stripping costs, a road contractor should be able to quarry and crush limestone or sandstone for not more than 75 cts. per cu. yd., or 62 cts. per ton of 2,000 lbs., wages and conditions being as above given.

The labor cost of erecting bins and installing a 9 × 16 jaw crusher, elevator, etc., averages about $75, including hauling the plant two or three miles, and dismantling the plant when work is finished. Further quarrying and crushing data are given in section on rock excavation.

Cost of Hauling.—Bins should always be erected to receive the broken stone, and the bottoms should have a slope of not less than 1 to 1, and be lined with sheet iron. If the slope is flat, say 1½ to 1, a wagon can not be loaded in much

less than 7 mins. and then a potato-hook or hoe must be used to keep the stone moving. But with a 1 to 1 slope, the stone runs freely and a wagon can be loaded in 2 mins. with 1½ cu. yds. In estimating the cost of loading wagons from bins it is well to allow 5 mins. per load, to cover little delays. Allow 5 mins. more to dump the wagon if it is a slat bottom wagon. Dump each load in three small piles, to reduce the labor of spreading. With team and driver at 35 cts. per hr., 1½ cu. yd. per load, and an average speed of 220 ft. per min., or 2½ miles per hr., the cost of hauling broken stone from bins and dumping it is 7 cts. per cu. yd., as the fixed cost for lost time loading and dumping, plus ½ ct. per cu. yd. per 100 ft. of one-way haul.

This rule may be expressed thus: *To a fixed cost of 7 cts. per cu. yd. add 25 cts. per mile measured one way from the bin to the dump.*

This rule applies to the loose stone measured in the wagon at the bin. I find that after traveling a short distance the loose stone jars down and compacts to a volume about 10% less. If the stone is estimated by the ton of 2,000 lbs., the rule becomes:

To a fixed cost of 6 cts. per ton add 20 cts. per ton per mile of haul measured one way.

The foregoing rules apply to a load of 1½ cu. yds., which is a fair load over hard earth roads. If the haul is all over macadam road, 2½ to 3 cu. yds. may be hauled per load, even where there are 5% grades. I have used coal wagons with fixed sides and solid bottom, which were unloaded by opening the end gate and two small gates in the middle of the wagon, one on each side. Such a wagon holding 3 cu. yds. may be unloaded by the driver in 16 mins.; and in half that time if another man assists the driver. On comparatively long hauls these wagons are to be preferred to slat bottom wagons, and if the work is near a city they can usually be rented at small cost.

In estimating the average length of haul on roadwork, bear in mind that the haul is never constant, and that at times the work will be too great for 5 teams, for example, but not enough to keep 6 teams fully busy. After estimating the cost by the above rules, for the actual average haul, I consider it fair to add about 15% to cover the added cost

due to variable haul, and the added cost of team time due to delays at the crusher.

Cost of Spreading.—Two men will assist the drivers in dumping their wagons and will spread the coarse stone, where 50 cu. yds. is the daily output of coarse stone from the crusher, provided the stone is dumped in small piles directly on the road and not off to one side. If the specifications require the stone to be dumped on platforms alongside the road and then shoveled into place, it will take at least four men instead of two. By all odds the cheapest way of spreading stone is to use a leveling scraper drawn by horses. With a Shuart grader, drawn by a team and operated by the driver and one man, 50 cu. yds. may be spread in 1 hr., at a cost of 1 ct. per cu. yd. It costs 1 ct. more per cu. yd. to complete the leveling of the stone by hand with a rake or potato-hook. The foregoing relates only to the coarse stone used in macadam, and not to the screening or binder which is put on after the coarse stone has been rolled and compacted. The screenings should not be dumped on the rolled stone, but in piles alongside the road, and spread with shovels; or the screenings may be spread directly from a wagon driven over the rolled stone, men walking behind the wagon with shovels which they fill from the wagon. From piles a man spreads 10 cu. yds. of screenings in 10 hrs., at a cost of 15 cts. per cu. yd.

Cost of Rolling.—The daily cost of operating a 10 or 12-ton steam road roller seldom differs much from the following average, except as to the price of coal.

	Per day.
Engineman	$3.00
½ night watchman's wages	0.75
0.35 ton coal at $6	2.10
Oil	0.30
2 tons of water pumped and hauled for boiler	0.75
Annual repairs ($150)	1.50
Annual interest ($150)	1.50
	$9.90

The annual repairs on roller seldom average less than 5% and often are 6% of the purchase price of the roller; these repairs include new rear wheels every 5 or 6 years,

new boiler tubes, etc., necessary to keep the roller as good as new. Moreover, these repairs must be charged up against 100 days actually worked each year. My estimate of 100 days, as an average, was published four years ago, and has been recently confirmed in the annual report of the Massachusetts Highway Commission. If, therefore, the first cost of the roller is $2,500, the annual interest charge, at 6%, is $150, which is equivalent to $1.50 per day actually worked; and an equal amount should be charged for repairs and depreciation.

A roller will average 40 cu. yds. of macadam, measured compacted after rolling, in a 10-hr. day, which is equivalent to 25 cts. per cu. yd. of macadam for rolling, or 4 cts. per sq. yd. of macadam 6 ins. thick.

One record that I have shows that in 72 working days of 8 hrs. each, a 10-ton roller thoroughly compacted 4,000 cu. yds. (24,300 sq. yds.) of 6-in. macadam on a gravelly sub-soil. This is equivalent to 55 cu. yds. of macadam per day. The macadam was laid in two courses, a 4-in. course of limestone and a 2-in. course of trap rock.

In rolling 6-in. macadam, at Hudson, N. Y., Mr. H. K. Bishop has found that 60 cu. yds. of compacted macadam, or 360 sq. yds., is the average 8-hr. day's work for a 10-ton steam roller. The roller was rented at $12 a day, including engineman and fuel, thus making the cost nearly 20 cts. per cu. yd. of macadam for rolling, not including sprinkling. The sprinkling was done from the village hydrants at a cost of less than 2 cts. per cu. yd. of macadam.

Cost of Sprinkling.—It requires about 4 cu. ft. of water per cu. yd. of compacted macadam to "puddle" the screenings or binder; but some inspectors are not satisfied with less than four times the necessary amount of water. In 10 hrs. one man, with a hand pump, will raise 1,000 cu. ft. of water 16 ft. high into a tank from which it can be drawn off into the sprinkler. A small gasoline driven pump gives a cheaper method of securing water where the amount of work warrants its purchase and installation. A two-horse sprinkler holding 60 cu. ft. of water is ordinarily used. Where the haul is short the driver can pump the water himself directly into the water wagon, for he can fill the wagon in half an hour, or less. If the haul is long, the lost team time is

reduced by using a tank from which the wagon can be filled in less than 10 mins. Ordinarily one sprinkling wagon, whose driver pumps the necessary water, will supply all the water needed to sprinkle the subgrade and puddle the macadam rolled by one steam roller. With long hauls and sandy subgrade, it will take two or more wagons. The number can be closely estimated, knowing the length of haul, by assuming 10 cu. ft. of water per cu. yd. of compacted macadam, which is sufficient to water the subgrade and puddle the macadam. If one wagon, at $4 a day for team and driver, is used, and 40 cu. yds. of macadam are laid, the cost is 10 cts. per cu. yd. for sprinkling.

Quantity of Stone and Binder Required.—In "Economics of Road Construction," I called attention to an error that had been copied in text books from a very early day down to the present, namely the statement that a layer of loose stone 6 ins. thick can be compacted under a roller till it is 4 ins. thick. No such compression is possible, but it often happens that the stone is driven 1 to 2 ins. into the subgrade. On a hard earth subgrade, it never requires more than 1.3 cu. yds. of coarse loose stone (exclusive of the screenings or binder) to make 1 cu. yd. of rolled or compacted stone, and where the stone is very tough the "compression" is even less. The percentage of binder or screenings required to fill the voids in the rolled stone varies somewhat with the thickness of the macadam. To ascertain the thickness of the coat of screenings necessary to fill the voids in the rolled stone, divide the thickness of the rolled stone by 4 and add ⅓ inch. Thus, for a 6-in. macadam road, there will be required $6 \div 4 + \frac{1}{3} = 1\frac{5}{6}$ ins. of screenings. This is equivalent to 0.3 cu. yd. of screenings per cu. yd. of macadam. Therefore, to make a cubic yard of finished 6-in. macadam requires 1.3 cu. yds. of coarse stone and 0.3 cu. yd. of screenings, or 1.6 cu. yds. measured in the wagons to make 1 cu. yd. of compacted macadam. Stated differently:

7.8 ins. of loose stone (½ to 2½-in.) will roll to 6 ins.
1.8 ins. of screenings (less than ½-in.) will fill voids.

9.6 ins. of loose stone and screenings will make 6 ins. of macadam.

If the stone weighs 2,400 lbs. per cu. yd., we need 1.56 short tons of coarse stone and 0.36 short ton of screenings, a total of 1.92 tons required to make 1 cu. yd. of finished macadam. If the stone is a heavy trap rock, weighing 2,700 lbs. per cu. yd., we need 1.75 short tons of coarse stone and 0.41 short ton of screenings, a total of 2.16 tons per cu. yd. of finished macadam. This estimate, based upon my own records, checks very well with records published by the Massachusetts Highway Commission.

On 2.6 miles of 6-in. New York State macadam, 1,600 cu. yds. of screenings were required to bind 4,000 cu. yds. of macadam rolled in place. This is equivalent to 0.4 cu. yd. of screenings per cu. yd. of macadam, or a depth of 2.4 ins. of loose screenings to bind the 6 ins. of rolled macadam. This large amount was due to the specification requirement that a "wearing coat" of screenings be left on the road.

The contractor is cautioned against careless examination of road specifications, for many engineers require the contractor to grade the subgrade exactly to grade and then put on enough stone to bring the finished macadam up to the established road grade. This causes the contractor to lose all stone that is driven into the subgrade by the roller, which in sand, or in soft wet clay, may amount to 2 ins. or more of loose stone.

Some specifications also foolishly require a ½-in. "wearing coat" of screenings to be left on the finished road, and this also amounts to a good many cubic yards of wasted material in a mile. The roadmaker will do well to carry in mind the following data: A bed 1 in. thick, 10 ft. wide and a mile long, contains 163 cu. yds. A bed 6 ins. thick, 16 ft. wide and a mile long, contains 1,564 cu. yds.

Summary of Cost.—Based upon the foregoing data, the cost of macadam is as follows:

Cost of stone (measured loose).	Per cu. yd.
Quarrying and crushing	$0.80
Quarry royalty	0.05
Hauling, say, 1½ miles	0.50
Spreading with shovels	0.15
Total per cu. yd. delivered and spread	$1.50

The quarrying includes 4 cts. per cu. yd. for stripping the earth.

Cost of macadam (measured packed).	Per cu. yd.
1.3 cu. yds. coarse stone, at $1.50	$1.95
0.3 cu. yd. screenings, at $1.50	0.45
Sprinkling	0.10
Rolling	0.25
½ foreman, at 40 cts. per hr	0.05
Total per cu. yd. in place	$2.80

This is equivalent to the following costs per square yard:

4-in. macadam	31 cts. per sq. yd.
6-in. macadam	47 cts. per sq. yd.
8-in. macadam	62 cts. per sq. yd.
9-in. macadam	70 cts. per sq. yd.

It will be remembered that wages of common laborers were assumed at 15 cts. per hr., and of teams at 35 cts. per hr. including driver. It will be noted that the cost of spreading is assumed for the worst conditions; but where the specifications permit, and where the contractor uses a leveling scraper, this item may be greatly reduced. The cost of hauling may also be greatly reduced if the specifications permit the hauling of loads over the newly laid macadam and if the work of macadamizing begins near the crusher. Few rocks are soft enough to yield a sufficiently large percentage of screenings to bind the macadam; in which case screenings must be imported, unless the specifications permit the use of loam, sand, or clay.

Macadam roads are usually made 4 to 6 ins. thick after rolling, and 12 to 16 ft. wide. I have often urged the more common use of single track macadam roads, 8 ft. wide, with turnouts (16 ft. wide) located every few hundred feet apart. In sparsely settled districts this would give an excellent road at a small cost per mile.

Cost of a Sandstone and Trap Macadam.—Near Rochester, N. Y., a macadam road 16 ft. wide and 6 ins. thick was built by contract, on a sandy soil. The bottom 4 ins. of the macadam were of sandstone bound with limestone screenings. The top 2 ins. were of trap rock bound

with limestone screenings. The sandstone was fieldstone obtained mostly from old stone fences near the road. Wages of common laborers were 15 cts. an hour; teams, 35 cts.

The cost of sandstone crushed and delivered on the road was as follows per cubic yard measured in the wagons:

	Cu. yd.
Paid farmers for fences	$0.10
Loading, hauling ½ mile, and crushing	0.80
Hauling 1 mile and spreading	0.35
Total	$1.25

The limestone screenings, used as a binder, were imported on canal boats, and delivered on the road cost as follows per cubic yard measured in the wagons:

	Cu. yd.
Screenings delivered on boats	$1.50
Unloading into wagons with derrick	0.25
Hauling 2 miles	0.30
Spreading on road	0.15
Total	$2.25

The cost of the trap rock was the same as for the limestone screenings. The cost of the 4-in. sandstone base was as follows:

	Cu. yd.
1.4 cu. yds. sandstone, at $1.25	$1.75
⅓ cu. yd. limestone screenings, at $2.25	0.75
Rolling and sprinkling	0.08
Total (measured in place)	$2.58

The cost of the 2-in. trap wearing coat was as follows:

1.4 cu. yds. trap, at $2.25	$3.15
⅓ cu. yd. screenings, at $2.25	0.75
Rolling and sprinkling	0.52
Total (measured in place)	$4.42

The 10-ton roller pushed much of the stone into the sandy subgrade, which accounts in part for the fact that it took

1.4 cu. yds. of loose stone to make 1 cu. yd. of rolled macadam. No very accurate record was kept of the amount of screenings used, but the amount stated is not far from correct. It will be noted that rolling the 4-in. lower course cost only 8 cts. per cu. yd. as compared with 52 cts. per cu. yd. for the 2-in. top course. This is due to the fact that the lower course was hastily rolled. Strictly speaking these two courses should not be treated separately in discussing the cost of rolling. The cost of rolling and sprinkling the two courses was 24 cts. per cu. yd.

Cost of Maintenance of Steam Rollers.—Mr. Thomas Aitken, who has used steam rollers for many years, is authority for the following data: The rear wheels of a roller lasted 7 years, during which time they consolidated 60,000 tons of road metal. The renewal of these wheels, together with other repairs and renewals of fire boxes, tubes, etc., amounted to $75 a year for 10 years. A set of 4 traction wheels and fore carriage for a 12-ton Aveling & Porter (England) roller cost $325; and the first cost of the roller was $2,000 in England. Aitken states that the cost of maintenance of a steam roller averages 5 to 6% per year.

Cost of a Limestone Macadam Road.—The following data apply to a limestone macadam road 6 ins. thick and 12 ft. wide, built by contract near Buffalo, N. Y., in 1898. The earth was a tough clay and ditches nearly 3 ft. deep were dug along both sides of the road. The cost of digging the ditches was nearly half the total cost of grading. The following was the cost of one mile of grading, including ditching and surfacing, in comparatively level country, the amount of excavation being about 4,600 cu. yds. (the graded road was 22 ft. wide between ditches):

Labor at $1.50 per 10-hr. day	$670
Teams at $3.50 per 10-hr. day	226
Foreman at $2.50 per 10-hr. day	97
Waterboy at $1.00 per 10-hr. day	17
Total per mile	$1,010

This is equivalent to about 22 cts. per cu. yd.

There were stretches of this road where ditches already existed, and the only grading required was to plow up the old surface, shape the trench to receive the macadam, and make the earth shoulders 5 ft. wide on each side of the macadam. Such stretches of grading cost $320 a mile.

The macadam was 6 ins. thick after rolling and 12 ft. wide. It was laid in two courses; (1) a foundation course of 1¼ to 2½-in. limestone, 4 ins. thick after rolling; and (2) a top course of ¾ to 1¼-in. limestone, 2 ins. thick after rolling. Both courses were bound with limestone screenings. As an average of 3¼ miles of road, it was found that loose stone spread to a depth of 6 ins. was rolled down with a 10-ton roller to an apparent thickness of 4 ins., but without doubt about 1 in. of stone was pushed into the subgrade and lost so far as the final measurement was concerned. It therefore took 1½ cu. yds. of loose (1¼ to 2½-in.) stone (measured in cars or wagons) to make 1 cu. yd. of rolled foundation course. For the top course it took a thickness of 2.8 ins. of loose (¾ to 1¼-in.) stone to give the required 2-in. thickness after rolling. This indicates also a further pushing of the foundation stone into the clay below, for all measurements of thickness were made with a level, and not by digging holes through the finished macadam. The average of these two courses was 1.46 cu. yds. of loose stone (not including screenings) to make 1 cu. yd. of rolled stone, but it took a trifle over ⅓ cu. yd. of limestone screenings (from size of dust up to ½-in.) to bind each cubic yard of rolled macadam. We have, therefore:

Loose stone	1.46 cu. yds.
Screenings	0.34 cu. yd.
Total	1.80 cu. yds.

This means that it required 1.8 cu. yds. of screenings and loose stone (measured in wagons) to make 1 cu. yd. of rolled macadam. The cost of each cubic yard of macadam was as follows:

Stone and screenings, f. o. b., 1.8 cu. yds., at $0.70	$1.26
Freight, 25 cts. ton, 1.8 cu. yds., at $0 28	0.50

Unloading cars into wagons, 1.8 cu. yds., at $0.11	0.20
Hauling ¾ mile, 1.8 cu. yds., at $0.28	0.50
Spreading, 1.8 cu. yds., at $0.08	0.14
Sprinkling	0.19
Rolling, including rolling subgrade	0.24
Total per cu. yd. of macadam	$3.03

Laborers received $1.50, and teams (with drivers) $3.50 per 10-hr. day.

Cost of Grading a Road,—A stiff clay was ditched and graded for a macadam road near Buffalo, N. Y., at the following cost per cu. yd.:

	Per cu. yd.
Plowing	$0.05
Loading into wagons	0.12½
Hauling 1,000 ft.	0.05½
Spreading	0.05
Foreman, supt., timekeeper and waterboy	0.05
Total	$0.33

The work was done by contract, and wages were $1.50 for common laborers, $4.50 for teams, per 8-hr. day. The clay was loosened with a rooter plow and was hauled in patent dump wagons. This cost is a safe figure for stiff material hauled not more than 1,000 ft.

The cost of grading 2½ miles of road under conditions essentially as above, except that the material was a gravelly soil, was 28 cts. per cu. yd.

Cost of Grading Roads With Road Machine.—Mr. Frank F. Rogers gives the following data on work done at Port Huron, Mich.: A street was to be macadamized with a strip of macadam 9 ft. wide and about 5 ins. thick after rolling. The earth was sand and sandy loam overlying clay. The side ditches had already been made, and the street was already well turnpiked (crowned), so that the grading consisted merely in preparing a bed for the macadam and in making earth shoulders to hold the stone. For this purpose a common road machine was used, first to cut

off the high places and fill the hollows by setting the blade at right angles with the center line of the street. Then, to form the shoulders and cut the crown of the subgrade, the blade was set at a slight angle so as to crowd enough earth to one side of the 9-ft. strip, forming first one shoulder, then the other. Stakes were set 1 ft. outside the 9-ft. strip to give line in operating the grader. The edges of the shoulders were afterward trimmed by hand with a shovel while the subgrade was being rolled with a steam roller. The grading cost $85 per mile in this soft sandy soil, where no ditching or turnpiking was done.

On another stretch of road, in sand, it was necessary to break up, re-grade, and trim the ditches to line, as well as to make the shoulders for the 9-ft. macadam. This cost about $360 per mile.

Two teams, a driver for each team and another man to operate the grader were used. Each team and driver received $3.50 for 10 hrs. and the other man received $1.50.

Cost of Crushing and Hauling Cobblestone.—On the work just described Mr. Rogers states that a 9 × 18-in. jaw crusher was used, with a rotary screen having three sizes of openings, ¾-in., 1½-in. and 2½-in. This crusher averaged 6⅔ cu. yds. of cobbles crushed per hour while actually working. In a run of 9½ cords (4.5 cu. yds.) of cobbles the output was 5.7 cu. yds., or an increase of 25% in volume after crushing.

The crushed stone was hauled from the bins in large spreader wagons, the steam roller hauling five of these wagons in a train, a distance of ¾ mile to the dumping place. On the best day, 76 cu. yds. were hauled ¾ mile, at a cost of 13 cts. per cu. yd. for hauling, distributed thus:

Wages of engineman	$2.00
Wages of helper	1.50
Fuel	2.00
Interest and depreciation taken at 16% ($400 per year) and distributed over 100 working days....	4.00
Total daily cost	$9.50

The roller and wide-tired spreader wagons were made by the Port Huron (Mich.) Engine & Thresher Co. The man who dumped the wagons was able to keep the road well trimmed at all times.

Mr. Rogers says in a letter to me: "The road roller sometimes hauled five wagons, but not always. It was not always convenient, as some of the wagons were often at the crusher loading, when trips would be made with three or four wagons, whichever was most convenient. The wagons held 3 cu. yds. when level full. Three wagons would haul about 10 cu. yds.

"The crusher had a 9 × 18-in. jaw opening. The stone was thrown from the cars in a large pile which must have been 100 ft. long at times. One man did the special feeding, that is saw that the jaws were kept full, but six men were required to wheel stone when running at the full capacity of the crusher. Besides these there was one foreman and an engineer. The wheelers were required to dump their wheelbarrows directly into the receiving hopper, thus leaving as little work as possible for the feeder. I have since found crushers that will crush Michigan cobbles with very little trouble from breakages, which were very annoying on this work."

On this work, in one case, the macadam was made of broken stone 6 ins. thick (measured loose before rolling) bound with a 2.11-in. (loose measure) layer of screenings; and in another case, the loose broken stone was 5.35 ins. thick, bound with 1.5-in. layer of screenings. The first named road cost $2,600 a mile, 9 ft. wide, exclusive of grading, but the grading cost only $85 a mile, as above given. This was an unusually low cost for grading, as the road was level, already ditched, and soft sand. While some would call the macadam a 6-in. macadam, strictly speaking it was not, since the 6 ins. were loose measure before rolling.

Cost of Resurfacing Old Limestone Macadam.—In Engineering News, June 6, 1901, I gave the following data to show that the intermittent method of repairing macadam is the most economic. The data were taken from my time

books and can be relied upon as being well within the probable cost of similar work done by contract under a good foreman. It will be noted that the cost of operating the roller is estimated at $10 per day. This includes interest and depreciation, as well as fuel and engineman's wages. The road was worn unevenly, but as it still had sufficient metal left, very little new metal was added.

The roller used was a 12-ton Buffalo Pitts, provided with steel picks on the rear wheels. It required 80 hours of rolling with the picks in to break up the crust of a surface 19,400 sq. yds. in area, 240 sq. yds. being loosened per hour. The crust was exceedingly hard and at times the picks rode upon the surface without sinking in, so that a lighter roller would probably have been far less efficient. In fact a 10-ton roller had been used a few years previous for the same purpose at more than double the expense per sq. yd., I am told. The picks simply open up cracks in the crust to a depth of about 4 ins. and it is necessary to follow the roller with a gang of laborers using hand picks to complete the loosening process. The labor of loosening and spreading anew the metal was 1,880 man-hours, or a trifle more than 10 sq. yds. per man-hour. About 60% of this time was spent in picking and 40% in respreading with shovels and potato hooks.

After the material had been respread, a short section was drenched with a sprinkling cart, water being put on in such abundance that when the roller came upon the metal, the screenings which had settled to the bottom in the spreading process were floated up into the interstices. The roller and sprinkling cart were engaged only 63 hours in this process, 300 sq. yds. being rolled per hour; an exceptionally fast rate. The rapidity of rolling was due to four factors: 1. The great abundance of water used, the water haul being very short. 2. The unyielding foundation (telford) beneath. 3. The abundance of screenings and fine dust, the road not having been swept for some time. 4. The great weight of the roller, which was run at a high rate of speed. I am not prepared to say that longer rolling would not have secured a harder surface, but I doubt very much whether it would. The metal, I should add, was hard

limestone. Summing up we find the cost of resurfacing this road per sq. yd. to have been as follows:

	Cts. sq. yd.
Picking with roller at $1 per hour	0.4
Picking by hand labor at 20 cts. per hour..........	1.2
Respreading by hand labor at 20 cts. per hour......	0.8
Rolling with roller at $1 per hour	0.33
Sprinkling with cart at 40 cts. per hour............	0.13
Foreman 143 hours at 30 cts. for 19.400 sq. yds......	0.44
Total	3.30

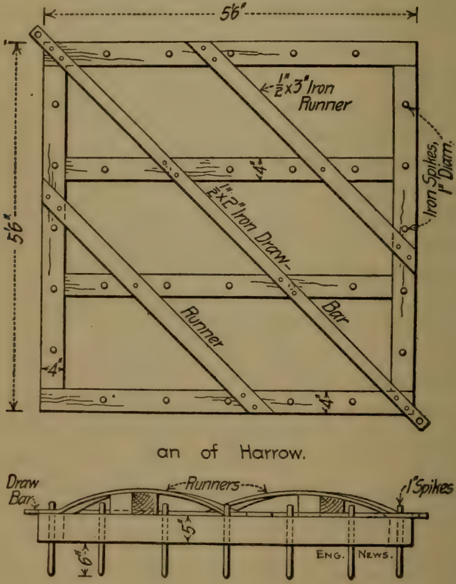
At this rate a macadam road 16 ft. wide can be resurfaced for little more than $300 a mile. The frequency with which such resurfacing is necessary will, of course, depend upon several factors, chief of which are the amount of traffic and the quality of road metal. I should say that five years would not be far from the average for a country road built of hard limestone. Unless the road has had an excess of metal used in its construction, new metal should be added at the time of resurfacing to replace that worn out.

I am unable to see how any system of continuous repair with its puttering work here and there can be as economical as work done in the manner above described. I would not be understood, however, as favoring an entire neglect of the road between repair periods. At times of heavy rains and snows, ditches and culverts need attention and there should be some one whose duty it is to look after such matters. What I do question is the economy of having a man continuously at work putting in patches upon the road.

Cost of Repairing Sandstone Macadam.—In Engineering News, Sept. 19, 1901, I described the method of repairing macadam streets in the Village of Albion, N. Y. The following is an abstract of the article:

"Using the method that I am about to describe, Mr. P. J. Stock succeeded in picking, resurfacing and rolling a stretch of sandstone macadam 18 ft. wide by 1,000 ft. long in two ten-hour days; one day in spiking up the old surface with the picks in the steam roller and one day in re-

rolling. As the surface was loosened to a depth of about 4 ins., it will be seen that over 200 cu. yds. of macadam were compacted by the 15-ton roller in 10 hrs. The point to which I wish to call attention is not so much the extraordinary rapidity of the rolling as the very ingenious method devised by Mr. Stock for completing the loosening of the macadam after cracking it up with the roller spikes.



Side Elevation.

FIG. 7.

For this purpose Mr. Stock built a heavy harrow, similar to those used on farms, Fig. 7, showing its detail design. By turning the harrow upside down it rides on the runners shown in the figure, and is thus transported when not in use. A heavy team of horses is used to drag the sharp-pointed harrow over the macadam after it has been loosened as much as possible with the spikes of the steam

roller. The spikes in the harrow not only complete the breaking-up of the crust as well as could be done by men using picks, but in addition the spikes spread the loosened stone, filling up all low places.

"The total cost of resurfacing was:

	Per sq. yd.
Roller and engineer at $1 per hour picking	0.5 ct.
Roller and engineer at $1 per hour re-rolling........	0.5 ct.
Sprinkling, with cart, 40 cts. an hour (1 day)........	0.2 ct.
Harrowing, team and driver 30 cts. an hr. (2 days)..	0.3 ct.
Total	1.5 cts.

"At this rate a macadam road 16 ft. wide and a mile long can be resurfaced for less than $140, or about half the cost given above. The cost of resurfacing has, therefore, been only $30 per mile per annum! Yet we are told that it is practically impossible to maintain macadam roads and pay interest on investment for $320 per mile per annum. (See discussion in Engineering News, April 25 and May 9, 1901.)

"The record made by Mr. Stock is indeed a remarkable one, and a record that few villages may hope to see attained unless by accident they secure an able Street Commissioner. In addition to the labor item there were some 75 cu. yds. of stone furnished, which it was estimated would bring the road up to its original crown. The stone cost about $60, delivered, and was spread by two men in two days at a cost of $6. By using a Shuart grader the item of spreading could have been reduced to $1.50.

"For new materials we have, therefore, a trifle over $60 per mile per annum, making a total of about $90 per mile per annum for labor and material for resurfacing a Medina sandstone road. Of course, the loss of material by wear was not accurately measured, but it was less rather than more than the amount put on for repairs. At this rate, the annual vertical wear was about 0.2-in. over the whole surface.

"Let it be remembered that this was a main traveled street, where farmers' teams enter the village, and that the residence streets may last another five years without re-

surfacing. In the face of such facts as these, I ask engineers who have condemned sandstone macadam for village streets and roads to give something besides abstract reasoning as a basis for their contention."

Cost of Scarifying Macadam.—Mr. Thomas Aitken is authority for the following English data:

When a macadam surface is to be picked, or scarified, by hand, soak the crust with water to soften it, unless it is the intention to screen the old materials. The depth to which the macadam is loosened by picks is usually about 2½ ins. One man will loosen at the following rate per day:

Soft macadam	33 sq. yds.
Hard macadam	20 sq. yds.
Very hard (steam rolled) macadam	12 to 15 sq. yds.

Large heavy harrows, or scarifiers, are much used in England, for resurfacing macadam. They are designed to be pulled along by a steam roller, ripping up the surface as they go. A scarifier with 3 teeth, spaced 6 ins. apart, is commonly used and will break up the macadam to a depth of 4 ins., at the rate of 300 sq. yds. per hour, if not interrupted by traffic. With the interruptions that ordinarily occur on a country road, 150 to 200 sq. yds. per hour is a fair average. Mr. Aitken gives one record of 650 sq. yds. per hr., loosening to a depth of 3 ins., using a 3-tooth scarifier drawn by a 15-ton roller. Each set of teeth, or tines, will scarify only 150 sq. yds. before sharpening; and it costs 5 to 10 cts. to sharpen each tine. A scarifier will do the work of 100 men.

Cost of Repairing Macadam in Mass.—The 1904 annual report of the Mass. Highway Commission is briefly abstracted in Engineering News, Apr. 13, 1905, p. 416. The repairing on 550 miles of macadam roads averaged less than $100 per mile for the year 1904, although the first of these roads was 10 years old.

In the Report for 1902, which is also abstracted in Engineering News, Apr. 23, 1903, p. 379, data on the cost of repairing three heavily traveled roads leading into cities are given.

Road.	Age, yrs.	Length.	Width.	Per sq. yd. per year, cts.	Tons stone per sq. yd., per yr.	Cost per ton in place.
Leicester.........	6	3,150	24	5.17	.03	$1.70
West Fitchburg...	7	2,200	15	5.15	.023	2.23
Beverly...........	6	2,150	18	5.20	.03	1.80

None of these roads had been repaired since the day it was built. The Leicester road leads into Worcester, and is much more heavily traveled than ordinary country roads. Even so, the cost of repairs per mile per year on these roads, for a width of 16 ft., is only $160.

Cost of Resurfacing Macadam.—In Trans. Am. Soc. C. E., Vol. 41, 1899, Mr. F. G. Cudworth gives the following data: An old macadam road was resurfaced with trap rock to the depth of 3 ins. after rolling with a 10-ton steam roller. It required 3.9 ins. of loose trap and 2.1 ins. of screenings to make the 3 ins. of compacted macadam, according to Mr. Cudworth, but there must have been an error in his estimate of the final thickness of the resurfacing (and it is a very easy matter to err in measuring rolled macadam). Possibly he did not measure the thickness of loose screenings left on the macadam, for 2.1 ins. of screenings is more than sufficient to fill the voids in 3 ins. of compacted stone. The steam roller averaged 472 sq. yds. or 40 cu. yds. of macadam per 10 hrs., at a cost of 2¾ cts. per sq. yd. for rolling and sprinkling. The cost of rolling and sprinkling was distributed as follows, and it should be noted that it does not include any allowance for rent of roller. On the other hand it is rare that a fireman is employed in addition to the engineman, and it is not always that the full wages of a night watchman are charged to the roller:

Engineman	$3.00
Fireman	1.50
Coal and oil	4.00
Sprinkler	3.00
Watchman	1.50
Total per day	$13.00

The total cost of resurfacing was as follows, not including cost of stone:

	Cts. per sq. yd.
Scraping and sweeping	2.00
Picking up old surface	1.50
Spreading stone	2.00
Rolling and sprinkling	2.77
Total per sq. yd.	8.27

Mr. W. C. Foster gives the following data: It was found that 7.38 ins. of loose trap rock on an old macadam pavement were rolled down to a thickness of 6 ins. under a 12-ton roller, a ratio of 1¼ cu. yds. of loose stone to 1 cu. yd. rolled. It was found in another case that 5.67 ins. of loose trap were rolled down to 4 ins., a ratio 1.42 to 1. The stone in both cases was trap, 1⅛ to 2¼-in. size. It was found that 1 cu. yd. of blue limestone screenings, sufficient to cover the rolled trap to a depth of 1.7 ins. over 21 sq. yds., was sufficient to bind 21 sq. yds. of 4-in. or 6-in. macadam. The loose stone and the screenings were measured in cars. I do not think that 5.67 ins. of loose trap can possibly be rolled down to 4 ins., furthermore I am sure that it takes more screenings to bind a 6-in. macadam than a 4-in. macadam. Mr. Foster says that in this work a 12-ton roller averaged 314 sq. yds., or 52 cu. yds., of 6-in. macadam per 10-hr. day.

Cost of Sprinkling Streets.—Mr. J. J. R. Croes says that to keep down the dust in Central Park, N. Y., from Apr. 1 to Oct. 31, about 100 cu. ft. of water were used daily per 1,000 sq. yds. of macadam, the greatest amount on any one day being 157 cu. ft. per 1,000 sq. yds. Carts holding 41 cu. ft. of water were used. Mr. E. P. North states that to keep down the dust on an earth road, water applied twice daily, there were 143 cu. ft. of water used daily per 1,000 sq. yds. A sprinkling cart holding 60 cu. ft. covered 850 sq. yds.

Mr. E. W. Howe gives the cost of sprinkling park roads (macadam) as follows per mile per year: Water (16 cts. per 1,000 gals.), $187; teaming, $533. The road was sprink-

led 10 times daily to keep the dust down, a sprinkler with fine holes being used. The cost of maintaining these roads was about $200 per mile per year, distributed thus: Screenings, $130; teaming, $50; labor, $20. As soon as a rut or a hole started, a small quantity of screenings was applied. This is a very expensive method of repairing, but not an uncommon one.

Cost of Telford Roads.—A telford road consists of a "bottoming," 6 to 12 ins. thick, made of rough stone blocks supporting a macadam surface 3 to 6 ins. thick. If the stone for the "bottoming" is limestone or sandstone that comes out in thin layers, readily shaped with a hammer into rectangular blocks, the "bottoming" is laid like a rough stone block pavement. But if the stone is a granite or trap that breaks out in irregular chunks, or if cobblestones are used, no attempt is made to lay a rough block pavement; and the "bottoming" then becomes a sort of macadam itself, consisting of large and small pieces. This last type of telford is the kind so largely used in the towns of northern New Jersey where trap rock is available.

The typical New Jersey telford is made of a "bottoming" 6 ins. thick, consisting of chunks of trap rock broken with hammers after delivery on the road until no chunk is more than 6 ins. thick. The spalls are packed in between the larger stone, and earth is shoveled over the stone from the side of the road until few stones are visible. Then a 5,500-lb. horse-roller is run over the stone before the 3-in. macadam is placed upon it. The macadam is bound with earth, and finally a thin layer of screenings is placed over all—more for appearance sake than for usefulness. The cost of quarrying the trap rock for the "bottoming" and the cost of crushing the portion of it that is used for the macadam surface, will be found on page 128.

In building a telford pavement on a New Jersey village street, the pavement was made 16 ft. wide. The stones for the bottoming were dumped from wagons, and a gang of 6 men broke the larger ones and placed them all by hand carefully so as to secure a compact "bottoming" 6 ins. thick. This gang of 6 men averaged 4 cu. yds. of bottoming laid per man per 10-hr. day, at a cost of 40 cts. per

cu. yd. for placing the "bottoming" after delivery. It took 1.2 cu. yds. of loose stones measured in the wagon to make 1 cu. yd. of "bottoming."

The macadam surface would have cost as much as any other macadam of equal thickness (3 ins.) had it not been for the use of earth as a binder instead of screenings. It took 1.2 cu. yds. of broken stone to make 1 cu. yd. of rolled stone, for a horse roller was used, and it did not compact the stone as much as a steam roller would. The cost of this broken stone can be estimated by data already given. The cost of rolling the "bottoming" and the macadam surface were not kept separately; but rolling both was as follows:

The 2½-ton roller, drawn by a team, averaged 150 lin. ft. of roadway 16 ft. wide per day 10 hrs., which is equivalent to 90 sq. yds. per day, at a cost of 4 cts. per sq. yd. By far the greater part of the rolling was confined to the 3-in. macadam. The team on the roller was taken off from time to time and hitched to a sprinkling cart. Water for sprinkling the macadam was obtained from a nearby hydrant. Summarizing the costs, we have the following:

Cost of bottoming (6 ins. thick).	Per cu. yd. in place.
Quarrying and loading 1.2 cu. yds. at 40 cts.	$0.48
Hauling 2 miles, 1.2 cu. yds. at 40 cts.	0.48
Placing	0.40
Total per cu. yd. in place	$1.36

Cost of macadam surface (3 ins. thick).	
Quarry and crushing 1.2 cu. yds. at 55 cts.	$0.66
Hauling 2 miles, 1.2 cu. yds. at 40 cts.	0.48
Spreading 1.2 cu. yds. at 12 cts.	0.14
Shoveling on earth for binder, 0.4 cu. yds. at 12 cts.	0.05
Sprinkling and rolling, 4 cts. per sq. yd.	0.48
Total per cu. yd. in place	$1.81

The cost per square yard, exclusive of grading the roadway, was:

	Per sq. yd.
1-6 cu. yd. bottoming at $1.36	$0.23
1-12 cu. yd. macadam at $1.81.....................	0.15
Total	$0.38

Laborers were paid 15 cts. per hr., and teams 35 cts. per hr. The cost of foremen is not included. The cost of the quarrying is given on page 128.

The foregoing relates to trap rock. If limestone or sandstone occurring in thin beds is quarried by wedging, and is roughly scabbled and laid like a paving, the cost of a telford "bottoming" is practically the same as for the slope-wall paving given in section on Masonry. The cost of the macadam surface may be estimated from data given on previous pages.

Cost of Laying Two Brick Pavements.—In Engineering News, July 24, 1902, I originally gave most of the following data on brick pavements:

The so-called "standard brick" for house building is 2¼ × 8¼ × 4 ins., and for a time brick for paving purposes were also made of the same dimensions. Within recent years the size of the standard brick for paving purposes has become 2½ × 8½ × 4 ins., and such bricks are commonly called "pavers." A larger size, 3¼ × 8½ × 4 ins., is also much used, and is known as "block." Some variations from these dimensions occur, as in Hallwood block, which is 3 × 9 × 4 ins.; and as neither the engineer nor the contractor can be sure of the exact size of brick that will be delivered, it is always necessary to secure from manufacturers a statement as to the sizes they make.

When the sizes are known there is a factor of uncertainty to the inexperienced, and that is the thickness of the grouted or tarred joints between bricks as ordinarily laid. I have found as the average of a large number of measurements that the thickness of the average joint is about ⅛ in., unless the pavers are made with projecting lugs to give a wider joint.

The accompanying table gives such data as will ordinarily serve in estimating the number of brick that will be required. Brick are occasionally laid with extremely close

joints about one-sixteenth inch, in which case about 3% more "pavers" laid on edge will be required than given in the table, but close laying is not only expensive work for the contractor, but objectionable also in that it is then impossible to fill the joints perfectly. For street pavements the bricks or blocks are laid on edge (making a brick pavement 4 ins. thick), but for sidewalks they are usually laid flatwise. I believe that in residence streets the bricks should usually be laid flatwise for true economy's sake.

Size of Brick.	—No. of Brick Per Square Yard.— With ⅛-in. Joints.	No Allowance for Joints.
2¼ x 8 x 4, laid flatwise	38.7	40.5
2¼ x 8 x 4, laid edgewise	67.1	72.0
2¼ x 8¼ x 4, laid flatwise	37.5	39.3
2¼ x 8¼ x 4, laid edgewise	65.1	69.8
2½ x 8½ x 4, laid flatwise	36.4	39.3
2½ x 8½ x 4, laid edgewise	57.2	61.0
3¼ x 8½ x 4, laid flatwise	36.4	38.1
3¼ x 8½ x 4, laid edgewise	44.5	46.9
3 x 9 x 4, laid flatwise	34.4	36.0
3 x 9 x 4, laid edgewise	45.5	48.0

Having obtained the price per thousand (M) for the paving brick, f. o. b. factory, and freight rate to destination, the weight of the bricks must be known to estimate total cost f. o. b. cars at destination. The specific gravity of paving brick ranges from 1.9 to 2.7. Tests of 12 Ohio makes show a range of 1.95 to 2.25.

Assuming a specific gravity of 2.2, a square yard of brick pavers 4 ins. thick would weigh 385 lbs., and a square foot would weigh 43 lbs., as laid with ⅛-in. joints. Whence, by taking from the bidding sheet the number of square yards of pavement and multiplying by 385, the total weight is readily ascertained; or, for all practical purposes, divide the number of square yards by 5, and the quotient will be the number of short tons of freight.

It is convenient to remember that a "paver" (2½ × 8½ × 4 ins.) weighs about 6¾ lbs. and a "block" (3¼ × 8½ × 4 ins.) weighs 8¾ lbs. These are actual averages of several makes of New York State bricks that I have used.

In unloading pavers from a flat car, one man will readily throw 10,000 pavers in 10 hrs. out to a man on a wagon, who will stack them in place. Where a large number of men are working under a foreman, 15,000 pavers will be

handled per man per day. In unloading the wagon, one man in the wagon tossing out brick to a man stacking them along the curb is required. With wages at 15 cts per hour, the cost of unloading cars is therefore 30 cts. per M, and a like amount for unloading wagons.

If the wagon haul is short, it will pay to have an extra wagon at each end of the haul to save team time, for it takes two men from 20 to 30 minutes to load and the same length of time to unload a wagon holding 1,000 pavers. Over paved streets 1,000 pavers, weighing 3½ tons, are a good wagon load, and it will tax a team to the utmost to pull such a load over earth a short distance at the end of the haul. Over good earth roads about 500 pavers are a fair load. Since a team at a walk travels about 2½ miles per hour, or 220 ft. per minute, the cost of hauling over paved streets is about 30 cts. per mile per M of pavers, wages being 35 cts. per hour for team and driver, to which must be added about 25 cts. per M for lost time of team (40 minutes) during loading and unloading when extra wagons are not provided.

A brick paving gang generally consists of about 15 men, whose duties are as follows:

4 pavers laying brick;
3 laborers loading barrows and wheeling brick;
1 laborer spreading sand cushion on concrete;
3 laborers grouting;
2 laborers ramming;
1 laborer raising sunken brick, etc.;
1 foreman.

Such a gang will lay 2,000 to 3,000 pavers per hour, which is equivalent to 5,000 to 7,500 bricks laid per brick layer in 10 hrs.

In paving a street with shale brick, at Jackson, Mich., there were about 200,000 bricks used for 3,500 sq. yds., or 57.1 bricks per sq. yd. The bricks were 2¾ × 4½ × 8 ins., with rounded corners. On a street 42 ft. wide, six brick-layers, supplied with brick by helpers, laid 70,000 bricks in 9 hrs. or 11,666 bricks per bricklayer. The ordinary aver-

age, however, was 7,000 bricks per bricklayer per day under favorable conditions. Note that the average day's output was only about two-thirds the best day's output.

The average wheelbarrow load is about 40 "pavers," or 270 lbs., and is seldom more than 45 "pavers," or 305 lbs. Such loads are readily wheeled over level runways and even up a short slope of 1 in 7. A man will readily load a barrow in 1¾ mins., at which rate, if he were doing nothing else but load barrows he would average 14,000 "pavers" loaded in 10 hrs. But the men who load the bricks usually wheel them to place and dump them. Where the distance to be wheeled is about 40 ft., it takes about ⅜ min. to go and return plus another ⅜ min. lost in dumping the barrow and in brief rests; so that a fair day's work is 10,000 "pavers" loaded and wheeled 40 ft.

The following is the actual cost on two different jobs:

	Cost per sq. yd. per hour, when gang lays 2,000 pavers. Cts.	Cost per sq. yd. per hour, when gang lays 3,000 pavers. Cts.
4 pavers at 25 cents per hour, each	2.9	1.9
8 laborers wheeling at 15 cents per hour	1.3	.8
1 laborer spreading sand	.4	.3
3 laborers grouting	1.3	.9
2 laborers ramming	.8	.5
1 laborer raising sunken brick	.4	.3
1 foreman at 30 cents per hour	.9	.6
Total	8.0	5.3

The above data are based upon the writer's experience, the lower cost being on a large job, but with union pavers who were not fast workers; the higher cost being on a small job where the work was finished before the force could be well organized.

It is frequently desirable to know what the cost will be of taking up, cleaning old brick and relaying. A gang of men, working leisurely, "by the day for the city," accomplished the following: Each laborer chipped the tar off 500 to 700 bricks in eight hours. Replacing a strip of pavement 4 ft. wide over a sewer required a gang of 17 men, employed as follows, after the pavement had been removed and concrete relaid:

	Wages for 8 hrs.	Cost per sq.. yd.
3 men toothing or chipping out bats......	$4.50	$0.08
6 pavers....................................	15.00	.25
2 men furnishing brick....................	3.00	.05
2 men ramming, etc........................	3.00	.05
4 men melting and pouring tar............	6.00	.10
Total....................................	$31.50	$0.53

The average per eight-hour day by the above gang was 60 sq. yds., the best day's work being 70 sq. yds.

It seems almost incredible that the cost of such repaving was 53 cts. a sq. yd., but it well illustrates the inefficiency of day labor for a city.

The following is a summary of the cost of paving with brick laid on edge, wages being 25 cts. per hour for pavers and 15 cts. for laborers:

	Cost per sq. yd.
57 "pavers" at $10 per M......................	$0.57
Hauling 1½ miles over earth roads	0.06
Laying pavers, including labor of grouting......	0.08
Materials for grout	0.05
1-36 cu. yd. sand cushion at $1.08 a cu. yd........	0.03
Plank to protect concrete	0.01
Total net cost	$0.80

To this, of course, must be added the cost of grading and the cost of a concrete base. Grading seldom costs more than 30 cts. per cu. yd., or 10 cts. per sq. yd., where the average cut is 1 ft. deep. The concrete base seldom costs more than $3 per cu. yd., or 50 cts. per sq. yd. Hence the total actual cost of a brick pavement, including grading and base, is about $1.40 per sq. yd., exclusive of contractor's profits, when prices and wages are as above.

The grout in these cases was mixed in the proportion of 2⅓ bbls. of Portland cement to 1 cu. yd. of sand, or in the ratio of 1:2½, a barrel of cement being considered to be 4½ cu. ft. The cost of a cubic yard of this grout, including the labor of mixing and spreading it, was as follows:

1 cu. yd. sand at $1.00	$1.00
2⅓ bbls. cement at $1.90	4.75
12 hrs. labor at 15 cts.	1.80
Total per cu. yd.	$7.55

1 cu. yd. of grout filled the joints in 120 sq. yds. of pavement; hence the cost was 6¼ cts. per sq. yd. for cement grout in joints, including labor. Where "blocks" are used, 1 cu. yd. of grout covers 160 sq. yds. of pavement, reducing the cost to less than 5 cts. per sq. yd., when prices are as above given. Grout is often mixed richer than in this case. To ascertain the quantity of cement per cubic yard of grout for any given mixture, use the data on page 253.

Cost of a Brick Pavement, Champaign, Ill.—Mr. Charles Apple gives the following data on the cost of a brick pavement laid in 1903 at Champaign, Ill. The work was done by contract, the contract price for grading being 23 cts. per cu. yd., and for brick pavement on concrete base, $1.29 per sq. yd.

The grading was done with drag-scoop scrapers, wheel-scrapers and wagons, each being used as demanded by the length of haul. Earth was loosened with plows to within 3 ins. of subgrade and this last layer then removed with pick and shovel.

The cost of removing the last 3 ins. was 2 cts. per sq. yd. with labor at $1.75 per day of 10 hours. There was a total of 26,715 cu. yds. of grading, and there were 38,504 sq. yds. of pavement.

The subgrade was compacted with a horse-roller weighing 150 lbs. per lin. in. at an average cost of about 0.05 cts. per sq. yd.

The concrete foundation was 6 ins. thick, composed of 1 part natural cement, 3 parts of sand and gravel, and 3 parts of broken stone. All the materials were mixed with shovels, and were thrown into place from the board upon which the mixing was done. The material was brought to the steel mixing board in wheelbarrows from piles where it had been placed in the middle of the street, the length of haul being usually from 30 to 60 ft.

When the concrete base had set, a sand cushion 1¼ ins. thick was placed upon it, and upon this the brick wearing surface was laid.

The cost of the brick wearing surface is given in the following table, and is based upon the assumption that 1,000 paving blocks will lay 25 sq .yds. of pavement, or 40 blocks per sq. yd. This ratio was determined by actual count after the pavement was laid. To this cost will have to be added something for rejected bricks, the amount depending upon how closely the inspection is done at the kilns.

Cost of 6-in. Concrete Base for Pavement.

	No. of men.	Sq. yds. per day.	Total wages.	Cost per sq. yd.
Rolling subgrade (1 roller, 2 teams, 1 driver)	1	8,000	$4.75	$0.0005
Mixing and tamping concrete:				
Turning with shovels	6	......	12.00	......
Throwing into place	4	......	8.00	......
Handling cement	2	......	3.50	......
Wetting with hose	1	......	1.75	......
Tamping	2	......	3.50	......
Grading concrete	1	......	1.75	......
Wheeling stone	6	......	10.50	......
Wheeling gravel	4	......	7.00	......
Foreman	1	......	4.00	......
Total	27	900	$52.00	$0.0580
Total labor per sq. yd.				$0.0585

For 1 sq. yd.:	Unit Price.	Quantity.	Cost.	
Cement	$0.50 a bbl.	⅕ barrel	$0.10	
Sand and gravel	1.00 cu. yd.	$\frac{1}{10}$ cu. yd.	.10	
Broken stone	1.40 cu. yd.	$\frac{1}{10}$ cu. yd.	.14	$0.34
Cost for material and labor per sq. yd.				$0.3985

This is practically 40 cts. per sq. yd., or $2.40 per cu. yd. of concrete for materials and labor. It is evident from the above quantities that a cement barrel was assumed to hold about 4.5 cu. ft., hence the cement was measured loose in making the 1 : 3 : 3 concrete. I am very much inclined to doubt the accuracy of the above given quantities of stone, gravel and cement. It will be noted that the labor cost of making and placing the concrete was only 35 cts. per cu. yd., wages being nearly $1.85 a day. This is so extremely low that I doubt the accuracy of the measurement of the work done. In fact I

do not hesitate to say that no gang of men ever made any considerable amount of concrete by hand at the rate of 5¾ cu. yds. per man per day.

Cost of Brick Block Wearing Surface.
(40 blocks per sq. yd.)

Labor:	Force working.	Amount of material handled per day.	Total daily wages.	Cost per sq.yd. cts.
Spreading sand cushion....	1 man	300 sq. yds.	$1.75	.57
Brick, cars to wagons.......	10 men	300 "	17.50	1.75
Hauling, 1 mile.............	8 teams	40 M. brick	24.00	2.40
Unloading, curb line........	8 men	40 "	14.00	1.40
Wheeling brick to layers...	2 men	40 "	3.50	1.15
Laying brick................	1 man	12 "	2.50	.83
Sweeping, inspecting and filling joints, sand........	1 man	450 sq. yds.	1.75	.39
Rolling pavement..........	1 team	800 "	3.00	.37
Total cost for labor for 1 sq. yd., cts..........				8.86

Material:	Amount.	Price.		
Sand cushion...........	$\frac{1}{36}$ yd.	$1.00 cu. yd.	......	$.0277
Brick, f.o.b. destination	40 sq. yds.	16.00 per M.	......	.6400
Sand filler..............				.0023
Total cost for material per sq. yd., cts........				67.00
Total cost, material and labor per sq. yd., cts........				75.87

Summary of Costs of Pavement.

Grading a sq. yd. at contract price of 23 cts. cu. yd............	$0.1000
Concrete base, a sq. yd..........	.3985
Brick wearing surface, a sq. yd..........	.7587
Total cost, a sq. yd..........	$1.2572

The contract price was $1.29. Note that the joints were filled with sand, and not with grout.

It will be noted that one paver laid 12,000 per day, and that each man wheeling averaged 20,000 per day. These are such very high records that they should not be taken as averages upon which to base an estimate of cost. At the rate of 20,000 per day, a man would wheel 50 cu. yds. of solid bricks in 10 hrs.! This might possibly be done if the wheeler did not have to load his own barrow, and if the haul was very short. Usually, however, the wheeler must load his own barrow from piles along the curb.

Each of the men loading blocks from cars to wagons averaged 12,000 blocks loaded in 10 hrs.; but each of the men unloading the wagons at the curb line averaged 5,000 blocks in 10 hrs.

Cost of a Brick Pavement in Minneapolis.—Mr. Irving E. Howe gives the following data on laying 17,000 sq. yds. of brick pavement in 1897. The work was not done by contract, but by day labor. Six weeks were required with a force of about 65 men. An old cedar block pavement on a plank foundation had to be removed, and the street graded. The subgrade was rolled with a 7-ton horse roller. A 6-in. concrete foundation was then laid, in proportion of 1 natural cement, 2 sand, 5 broken stone. There were required 1.16 bbls. of natural cement per cu. yd. of concrete, at 76 cts. per bbl. The stone cost $1.15 cts. per cu. yd. delivered, and the sand cost 30 cts. per cu. yd. delivered. The total cost of the concrete laid was $2.80 per cu. yd. Laborers mixing received $1.75 per day. The Purington Paving Brick Co., of Galesburg, Ill., furnished 198 car loads of brick, $2\frac{1}{4} \times 4 \times 8$-in. size, guaranteed to lay 56 to the sq. yd., costing the city $15.50 per M, or 87 cts. per sq. yd. on the cars at Minneapolis. The manufacturers guaranteed the bricks for ten years. A 1-in. sand cushion was laid on the concrete. To secure a perfect crown 1-in. strips of wood were nailed to the concrete every 12 ft., from curb to curb. An iron shod straight edge or scraper was placed on these strips and dragged across the street to bring the sand cushion to a perfect surface. Then one of the wood strips was pulled up and moved ahead. After a block of bricks had been laid, they were rolled with a roller, broken bricks replaced, and the joints grouted under a special contract of 17½ cts. per sq. yd. for the grouting. Exclusive of this grouting the actual cost per square yard was as follows:

	Per sq. yd.
Removing old cedar paving	$0.035
Grading	0.032
Concrete, natural cement, 6 ins. thick	0.467
Planking over concrete, lumber, etc	0.008
56 bricks at $15.55 per M	0.870
Hauling brick	0.038
Sand cushion, 1-in., at 65 cts. cu. yd	0.018
Laying brick	0.032
Total per sq. yd. (not incl. grout)	$1.500

The pavers received $2 a day, laborers $1.75, teams $3.50. It will be noticed that the hauling cost 68½ cts. per M of bricks.

Cost of a Brick Pavement, Memphis, Tenn.—Mr. Niles Meriwether gives the following data on the cost of 1,300 sq. yds. of brick pavements laid by day labor (probably colored) in 1893:

	Per sq. yd.
Removing old material and grading	$0.23½
Concrete base (8-in.):	
Natural cement, at $0.74 per bbl.	0.19½
Sand, at $1.25 per cu. yd.	0.07½
Broken stone, at $1.87 per cu. yd.	0.35½
Labor hauling stone and making concrete	0.15½
Sand cushion	0.07
62 paving bricks, at $18.20 per M.	1.13
1-25 bbl. pitch, at $5.25	0.21
Sand used in pitching	0.01
Labor paving and pitching	0.15
Total	$2.58½

The cost of curbs distributed over the pavement added 10 cts. more per sq. yd. Common laborers were used to lay the bricks, at $1.25 to $1.50 per day of 8 hrs. The mortar for concrete was mixed 1 : 2, and enough mortar used to fill the voids in the stone. It took 1.36 bbls. of Louisville cement per cubic yard of concrete. On three other jobs of about the same size, the costs were practically the same as above. On one street Hallwood blocks were used, requiring 50 blocks per sq. yd., and 1 bbl. of pitch for every 25 sq. yds. On one job, where Virginia paving bricks were used, 56 bricks were required per sq. yd., and the labor cost of laying the brick and pitching the joints was 11 cts. per sq. yd.

It will be noted that the cost of materials was unusually high, and that the labor was not efficient.

Cost of Chipping Tar Off Bricks.—When a brick pavement with tar joints is taken up, the tar must be chipped off the old bricks before re-laying them. This is usually done with a hatchet, after cooling the bricks in a bucket

or tub of water. As an average of a good many thousand brick thus cleaned, I found that one laborer could be counted upon to clean 60 bricks per hour. With wages at 15 cts. per hr., this is equivalent to $2.50 per M for cleaning the bricks.

Cost of a Stone Block Pavement.—In Engineering News, July 24, 1902, I originally gave the following data on stone block pavements:

We have first to consider the dimensions of the blocks. When made of granite, they are split with wedges to tolerably uniform sizes; but when of stratified rock, like Medina sandstone, a carload of blocks will show wide variation in size of individual stone. In depth, of course, the blocks must be quite uniform, and 6 ins. depth is usually specified. In New York City 4 ins. is specified as the maximum width of granite blocks, and it may be assumed as a certainty that they will not be found less than the maximum allowed, since to split them of less width out of granite would add materially to the cost per square yard. In Rochester, N. Y., 5½ ins. is specified maximum width for Medina blocks but, due to the thin stratification of the stone, they frequently come 3 ins. in width. The maximum length specified is usually 12 ins., the mimimum 8 ins. Granite blocks which are quite uniform in size are sold by the 1,000, and sometimes by the square yard, laid. Medina blocks vary so in size that they are sold by the square yard.

Joints are ordinarily about ½-in. wide, and are filled first with gravel or sand, into which hot tar is poured. In New York City hot gravel is first poured in to the depth of 2 ins. and hot tar poured upon it till voids are filled; then another 2-in. layer of gravel and tar is added, and so on until the joint is full. By this method one-third to half the volume of the joints is tar. In Rochester the Medina sandstone joints are first filled clear to the surface with hot sand (damp sand will not run); then men with pointed wire pins like a surveyor's "stick-pin," used in chaining, force the sand down or pick it out if there is an excess, until the surface of the sand is 1½ to 2 ins. below the surface of the block pavement. Hot tar is then poured in

and fills the upper 2 ins. of the joint without penetrating to the bottom. This method gives as good satisfaction, apparently, as the New York method.

In order to economize tar, which is quite an item, the writer would suggest a combination of the two methods; that is, first fill the joint with sand to within 2 ins. of the surface, then fill the upper 2 ins. with hot pea gravel (screened) and pour in tar.

Cement grout has been used as a joint filler, but since a cement joint, once cracked, does not heal as a tar joint does, cement appears less adapted for filling the necessarily wide joints of a stone block pavement.

With blocks $3\frac{1}{2} \times 12 \times 6$ ins., there are 26 per sq. yd. where joints are ½-in. and the area of joints is 13% of the total area, and the volume of joint filler is nearly 0.6 cu. ft. per sq. yd. of pavement. If tar is worth 10 cts. a gallon, or 75 cts. a cu. ft., and one-third the volume of the joint is tar, the cost for tar alone will be $0.6 \times \frac{1}{3}\ 75 = 15$ cts. per sq. yd. of pavement.

In unloading flat cars, the stone paving blocks may be slid down an iron chute into the wagon. One man will pitch out to one man stacking blocks up in the wagon about 10 sq. yds. of paving blocks (6 ins. deep) per hour, which, with wages at 15 cts. per hour, would cost 3 cts. per sq. yd. for unloading from cars to wagon. The cost of unloading wagon and stacking up on sidewalk will be about the same.

Assuming that extra wagons are not used, but that the driver works at loading and unloading, we arrive at the total cost of hauling as follows: A wagon will carry not much to exceed 6 sq. yds. (6 ins. deep) of blocks weighing about 5,400 lbs. over paved streets, and if only one man assists the driver loading and unloading, it will require about one hour and a quarter to load and unload 6 sq. yds. With wages of driver and team at 35 cts. an hour and of laborer at 15 cts., we have the fixed cost of loading and unloading about 10 cts. a sq. yd. The cost of hauling will be about 5 cts. per sq. yd. per mile of haul (lead) over pavements and 10 cts. over earth roads.

After the blocks are stacked up at the sides of the street they must be laid out on edge in the street in advance of

the pavers and assorted into sizes of uniform thickness, which laborers using wheelbarrows will do at a cost of about 3 cts. a sq. yd. Two skilled pavers, with one laborer as a helper to supply stone, form a gang. A paver will lay 5 to 8 sq. yds. an hour; 6 sq. yds. may be taken as an average for safe estimating, which, with pavers' wages at 30 cts. an hour and labor at 15 cts., makes cost of laying 6 cts. per sq. yd. Following the pavers, comes a gang of 3 men ramming and raising sunken stone, 1 screening sand for joints, 2 heating sand and tar, 1 wheeling sand for joints, 1 sweeping sand into joints, 7 poking sand down into joints and digging out excess, 5 filling upper 2 ins. of joints with tar, making a gang of 20 men following the pavers, and with wages at 15 cts. an hour, such a gang covering 60 sq. yds. an hour, makes the cost of ramming and filling joints 6 cts. a sq. yd. Summing up, we have for the total labor cost:

	Per sq. yd.
Loading and unloading inclusive of lost team time	$0.10
Hauling 1 mile	.05
Distributing blocks	.03
Laying	.06
Filling joints	.06
Foreman at 40 cts. per hr., 30 sq. yds.	.013
2 water and errand boys	.007
Total labor	$0.32

Cost of Medina block pavement:

	Per sq. yd.
1/3 cu. yd. street excavation	$0.15
6-in. concrete foundation	.50
1-18 cu. yd. sand cushion in place at $1.08	.06
Medina block (6-in.) f. o. b. Albion, N. Y.	1.15
Freight to Rochester	.07
Unloading, hauling and laying	.30
1.5 gallons tar at 10 cts. a gallon	.15
1-50 cu. yd. sand for joints	.02
Total	$2.40
Add for contractor's profit	.25
Total cost	$2.65

In paving four streets with Medina sandstone blocks, at Rochester, N. Y., the average amount of joint filler was 1.4 gallons of paving pitch per sq. yd.

The foregoing cost data apply to work done over large areas with fairly well organized gangs; but on small areas, such as paving gutters 3 ft. wide, I have had pavers average only 3½ sq. yds. per hour per paver, each paver securing his own blocks from piles along the curb.

Cost of Granite Block Pavement on Concrete.—Mr. G. W. Tillson, in "Street Pavements and Paving Materials," p. 204, gives the following data on the cost of granite block pavement in New York City in 1899. The day was 10 hrs. long:

Concrete gang:	Per day.
1 foreman	$3.00
8 mixers on two boards, at $1.25	10.00
4 wheeling stone and sand, at $1.25	5.00
1 carrying cement and supplying water, at $1.25	1.25
1 ramming, at $1.25	1.25
Total, 240 sq. yds. (40 cu. yds.), at 8.6 cts.	$20.50

The concrete is shoveled direct from the mixing boards to place.

Cost 1 : 2 : 4 concrete:	Per cu. yd.
1⅓ bbls. natural cement, at $0.90	$1.20
0.95 cu. yd. stone, at $1.25	1.19
0.37 cu. yd. sand, at $1.00	0.37
Labor	0.51
Total per cu. yd.	$3.27

With concrete 6 ins. thick this is equivalent to 54.6 cts. per sq. yd. for the concrete foundation.

The granite blocks were laid two days' later with the following gang:

	Per sq. yd.
Labor	$0.14
30 Belgian blocks, at $30 per M delivered	0.90
0.2 cu. yd. sand, at $1	0.20
Total	$1.24

A gang laying granite block pavement on sand was as follows:

	Per day.
4 pavers, at $4,50	$18.00
2 rammers, at $3.50	7.00
3 chuckers, at $1.50	4.50
3 laborers, at $1.25	3.75
Total, 280 sq. yds., at 12 cts.	$33.25

On another street where there were street-car tracks the labor cost was 10% more.

	Per sq. yd.
Labor	$0.12
24 granite blocks, at $55 per M	1.32
0.2 cu. yd. sand, at $1	0.20
Total	$1.64

	Per day.
10 pavers, at $4.50	$45.00
5 rammers, at $3.50	17.50
6 chuckers, at $1.50	9.00
20 laborers, at $1.25	25.00
2 foremen, at $3.50	7.00
Total, 650 sq. yds., at 16 cts.	$103.50

	Per sq. yd.
Labor laying blocks	$0.16
22½ granite blocks, at $55 per M.	1.24
3½ gals. paving pitch, at 7 cts.	0.24
1⅓ cu. ft. gravel for joints, at $1.95 per cu. yd.	0.10
1½ cu. ft. sand for cushion, at $1.00 per cu. yd.	0.06
1 sq. yd. concrete	0.55
Total	$2.35

Cost of Laying Asphalt Pavements at Winnipeg.—The following data are given by H. N. Ruttan, City Engineer of Winnipeg, Manitoba, on the cost of laying asphalt with a municipally owned plant. In 1899, the city purchased

a second-hand stationary plant for $12,322, and made the following additions:

New 10-ton roller	$3,500
New sheds, etc.	733
Tools bought 1899	262
Tools bought 1900	121
Maintenance 1899	568
Maintenance 1900	1,048
	$6,232
Second-hand plant	12,322
Total	$18,554

The maintenance items consisted largely in repairs to the second-hand plant necessary to put it in first-class condition. The plant includes 2 asphalt melting tanks, sand drum, cold and hot sand elevators, millstone for grinding limestone, storage tank for hot asphalt, storage bins for ground limestone and hot sand, mixer of 7 cu. ft. capacity, 60-HP. boiler, 30-HP. engine, air compressor and receiver, 5-ton roller, 10-ton roller, and accessories. The force required to operate the mixing plant was as follows:

1 superintendent	$8.00
1 engineman	3.00
2 firemen	4.00
2 asphalt melters	4.00
1 asphalt dipper and mixer	2.00
1 measurer of sand and limestone	2.00
2 sand and limestone shovelers	2.00
1 record keeper	4.00
1 man for odd jobs	2.00
Total labor for 9 hrs	$31.00

I have assumed the above rates of wages, but it is stated that the total cost of operating was $40 a day, which doubtless includes the cost of 1½ or 2 tons of coal. It is stated that in 1900 the prices of materials and labor were as follows, on cars:

Asphalt. per short ton	$36.00
Portland cement, per bbl.	3.65
Sand, per cu. yd.	1.35
Broken stone, per cu. yd.	1.10

Common labor is said to have been 17½ to 20 cts. per hr.; teams, 40 cts. per hr.

Asphalt pavement, consisting of 1½-in. binder and 2-in. wearing surface, laid on a 4½-in. Portland cement concrete foundation, cost $2.04 per sq. yd. for materials and labor. The concrete foundation cost $0.74 per sq. yd., leaving $1.30 per sq. yd. for the asphalt, provided the grading was not included in the $2.40—which is nowhere mentioned. It will be noticed that interest and depreciation are not included. The plant has a capacity of 1,000 sq. yds. of 2-in. wearing surface, or 1,500 sq. yds. of 1½-in. binder, which is equivalent to saying that it has a capacity of about 60 cu. yds. of asphalt, measured in the street, per day of 9 hrs. In 1899 the city laid 45,800 sq. yds.; in 1900, it laid 22,000 sq. yds. If we assume 30,000 sq. yds. as a fair average for a term of 10 years, the plant would pay for itself by charging 6 cts. per sq. yd. for plant, and it would be occupied about 60 days of actual work per year. But we should not lose sight of the fact that the services of an expert to run the plant could not be secured on the basis of a few dollars a day for only a small fraction of the year. Indeed the cost of an expert's annual salary alone might very easily run up the cost an amount equivalent to 10 cts. per sq. yd.

Since the above was written I have secured the following additional data for the year 1903. The plant has been enlarged and its estimated value is now $21,082. The charges against this plant for the year 1903 were as follows:

Maintenance and repairs	$2,297
½ cost of new tools	236
4% interest on $21,082	843
5% depreciation on $21,082	1,054
Lost taxes	100
Total	$4,530

In 1903 there were laid 65,381 sq. yds., so that the charge for plant was 6.93 cts. per sq. yd. The soil is clay and upon it is spread 3 ins. of sand and gravel before laying the concrete base. The cost of the pravement in 1903, including grading, was as follows:

	Per sq. yd.
Grading, including cross-drains	$0.15
Sand, 3-in. foundation	0.15
Concrete, 4½ ins. thick	0.65
Binder coat	0.28
Surface coat	0.60
Plant charges	0.07
Total	$1.90

The prices paid for materials, f. o. b. Winnipeg, were as follows:

Portland cement, per bbl.	$2.96
Broken stone, per cu. yd.	1.30
Sand and gravel, per cu. yd	1.00
Crushed granite, per cu. yd.	5.00
Asphalt, per ton	26.37
Maltha, per imp. gal.	0.12
Common labor, per 9-hr. day .... $1.80 to	2.25
Skilled labor, per 9-hr day	2.70
Foremen .... $3.00 to	4.00
Superintending chemist (for 5 or 6 mos.)	8.00

Mr. Ruttan informs me that a surface coat (Bermudez) costs as follows:

900 lbs. sand (0.4 cu. yd.)	$0.54
140 lbs dust	0.18
Fuel, cordwood	0.12
Labor	0.32
23 lbs. oil at 1½ cts.	0.34½
100½ lbs. Bermudez (gross), at $1.932	1.94
Total for 1,157 lbs.	$3.44½
Cost per sq. yd. (175 lbs. per sq. yd.)	$0.52

Cost of Laying Asphalt Pavement.—The following shows the labor cost of laying asphalt on a concrete base at Rochester, N. Y. A binder coat, ½-in. thick, was first laid; then a wearing, or surface coat 1½ ins. thick; making a total of 2 ins. The gang consisted of 16 men, organized as follows:

Binder gang.	Surfacing gang.
4 barrow loaders.	4 shovelers.
4 barrow wheelers.	5 rakers.
2 rakers.	2 tampers.
2 tampers.	2 smoothers.
1 wagon unloader.	1 cement spreader.
1 tar melter.	1 iron heater.
1 iron heater.	1 foreman.
1 foreman.	16 men.
16 men.	

The binder gang averaged 2,250 sq. yds. in 10 hrs. of ½-in. binder coat laid, although they frequently laid 390 sq. yds. in an hour. In surfacing work, the gang averaged 1,800 sq. yds. of 1½-in. surfacing coat in 10 hrs., although they frequently laid 260 sq. yds. in an hour. There were two asphalt steam rollers constantly at work, with this gang of 16 men. In laying several thousand yards of this 2-in. asphalt pavement, I found the average labor cost to be as follows:

15 laborers at $1.50	$22.50
1 foreman at $4.00	4.00
2 roller engineers at $3.00	6.00
Fuel for rollers	2.50
Total for 1,000 sq. yds. of 2-in. asphalt	$35.00

This is equivalent to 3½ cts. per sq. yd. for laying and rolling.

The haul from the mixer to the street was 3 miles, and each team made 4 trips daily, averaging 1½ cu. yds. of loose material per load. It took 2¾ cu. yds. of loose material in the wagons to make 2 cu. yds. packed by the roller. The wagons were slat-bottom wagons, and it took about

8 mins. to dump a wagon, but fully as much more time was lost waiting for other wagons, turning around, etc., which time was made up by trotting back. There were 17 teams kept busy, at $3 per day each, making the cost 5 cts. per sq. yd. for hauling the asphalt 3 miles.

Cost of Cement Walks.—The cost of cement walks is commonly estimated in cents per square foot. including the necessary excavation and the cinder or gravel foundation. The excavation usually costs about 13 cts. per cu. yd., and if the earth is loaded into wagons the loading costs another 10 cts. per cu. yd., wages being 15 cts. per hr. The cost of carting depends upon the length of haul, and may be estimated from data given on page 83. If the total cost of excavation is 27 cts. per cu. yd., and if the excavation is 12 ins. deep, we have a cost of 1 ct. per sq. ft. for excavation alone. Usually the excavation is not so deep, and often the earth from the excavation can be sold for filling lots.

In estimating the quantity of cement required for walks, it is well to remember that 100 sq. ft. of walk 1 in. thick require practically 0.3 cu. yd. concrete. The base of the walk is often made 3 ins. thick, of 1 : 3 : 6 concrete, and the top wearing coat is often made 1 in. thick of 1 : 1½ mortar. The cement is invariably Portland.

Such a walk is frequently laid on a foundation of gravel or cinders 4 ins. thick.

If the concrete base is 3 ins. thick, we have 0.3 × 3, or 0.9 cu. yd. per 100 sq. ft. of walk. And by using the tables on page 255, we can estimate the quantity of cement required for any given mixture. In cement walk work the cement is commonly measured loose, so that a barrel can be assumed to hold 4.5 cu. ft. of cement. If the barrel is assumed to hold 4.5 cu. ft., it will take less than 1 bbl. of cement to make 1 cu. yd. of 1 : 3 : 6 concrete; hence it will not require more than 0.9 bbl. cement, 0.9 cu. yd. stone, and 0.45 cu. yd. sand per 100 sq. ft. of 3-in. concrete base. The 1-in. wearing coat made of 1 : 1½ mortar requires about 3 bbls. of cement per cu. yd., if the barrel is assumed to hold 4.5 cu. ft. (see page 253); and since it takes 0.3 cu. yd. per 100 sq. ft., 1 in. thick, we have 0.3 ×

3, or 0.9 bbl. cement per 100 sq. ft. for the top coat. This makes a total of 1.8 bbls. per 100 sq. ft., or 1 bbl. makes 55 sq. ft. of 4-in. walk.

As the average of a number of small jobs, my records show the following costs per sq. ft. of 4-in. walk such as just described:

	Cts. per sq. ft.
Excavating 8 ins. deep	0.65
Gravel for 4-in. foundation, at $1.00 per cu. yd.	1.20
0.018 bbl. cement, at $2.00	3.60
0.009 cu. yd. broken stone, at $1.50	1.35
0.006 cu. yd. sand, at $1.00	0.60
Labor making walk	1.60
Total	9.00

This is 9 cts. per sq. ft. of finished walk. The gangs that built the walk were usually 2 masons at $2.50 each per 10-hr. day with 2 laborers at $1.50 each. Such a gang averaged 500 sq. ft. of walk per day.

Cost of Cement Walks in Iowa.—Mr. L. L. Bingham sent out letters to a large number of sidewalk contractors in Iowa asking for data of cost. The following was the average cost per square foot as given in the replies:

	Cts. per sq. ft.
Cement, at $2 per bbl.	3.6
Sand and gravel	1.5
Labor, at $2.30 per day (average)	2.2
Incidentals, estimated	0.7
Total per sq. ft.	8.0

This applies to a walk 4 ins. thick, and includes grading in some cases, while in other cases it does not. Mr. Bingham writes me that in this respect the replies were unsatisfactory. He also says that the average wages paid were $2.30 per man per day. It will be noted that a barrel of cement makes 55½ sq. ft. of walk, or it takes 1.8 bbls. per 100 sq. ft.

The average contract price for a 4-in. walk was 11½ cts. per sq. ft.

Cost of a Cement Walk, San Francisco.—Mr. George P. Wetmore, of the contracting firm of Cushing & Wetmore, San Francisco, gives the following:

The foundations of cement walks in the residence district of San Francisco are 2½ ins. thick, made of 1 : 2 : 6 concrete, the stone not exceeding 1 in. in size. The wearing coat is ½-in. thick, made of 1 part cement to 1 part screened beach gravel. The cement is measured loose, 4.7 cu. ft. per bbl. The foundation is usually laid in sections 10 ft. long; the width of sidewalks is usually 15 ft. The top coat is placed immediately, leveled with a straight edge and gone over with trowels till fairly smooth. After the initial set and first troweling, it is left until quite stiff, when it is troweled again and polished—a process called "hard finishing." The hard finish makes the surface less slippery. The surface is then covered with sand, and watered each day for 8 or 10 days. The contract price is 9 to 10 cts. per sq. ft. for a 3-in. walk; 12 to 14 cts. for a 4-in. walk having a wearing coat ¾ to 1-in. thick. A gang of 3 or 4 men averages 150 to 175 sq. ft. per man per day of 9 hrs. Prices and wages are as follows:

Cement, per bbl.	$2.50
Crushed rock, per cu. yd.	1.75
Gravel and sand for foundation, per cu. yd.	1.40
Gravel for top finish, per cu. yd.	1.75
Finisher wages, best, per hr.	0.40
Finisher helper, best, per hr.	0.25
Laborer, best, per hr.	0.20

Cost of a Cement Walk, Forbes Hill Reservoir.—Mr. C. M. Saville, M. Am. Soc. C. E., gives the following data relating to 6,250 sq. ft. of cement walk built by contract:

Stone foundation.	Per cu. yd.	Per sq. ft.
Broken stone for 12-in. foundation	$0.40	$0.015
Labor placing same, 15 cts. per hr.	1.50	0.056
Total	$1.90	$0.071

Concrete base (4½ ins. thick).		
1.22 bbls. cement per cu. yd., at $1.53........	$1.87	$0.026
0.50 cu. yd. sand per cu. yd., at $1.02..........	0.51	0.007
0.84 cu. yd. stone per cu. yd., at $1.57........	1.32	0.019
Labor (6 laborers and 1 team)	3.48	0.050
Total (for 90 cu. yds.)................	$7.18	$0.102
Top finish (1 in. thick).		
4 bbls. per cu. yd., at $1.53	$6.12	$0.019
0.8 cu. yd. sand, at $1.00	0.80	0.002
Lampblack	0.29	0.001
Labor (2 walk masons and 1 helper)........	6.36	0.016
Total	$13.57	$0.038

This walk was 6 ft. wide laid on a 12-in. foundation of broken stone. On top of this foundation was the concrete base, 5 ins. thick in the middle and 4 ins. thick at the sides. This base was surfaced with a top granolithic finish about 1 in. thick.

It is difficult to account for the high labor cost ($1.50) of placing the 12-in. stone foundation except on the supposition that the stones were broken by hand.

The work on the concrete base was unusually expensive, for no apparent reason except inefficiency of the men.

The two masons received $2.25 each per day, and their helper $1.50, and they averaged 360 sq. ft. per day, or 60 lin. ft. of walk 6 ft. wide, which is equivalent to 1⅔ cts. per sq. ft.

Atlas cement was used, and in measuring was assumed to be 3.7 cu. ft. per bbl.

Cost of Concrete Curb and Gutter.—The following costs were recorded by Mr. Charles Apple, and relate to work done at Champaign, Ill., in 1903. The work was done by contract, at 45 cts. per lin. ft. of the curb and gutter shown in Fig. 7a.

The concrete curb and gutter was built in a trench as shown in the cut. The earth was removed from this trench with pick and shovel at a rate of 1 cu. yd. per man per hour. The concrete work was built in alternate sec-

tions, 7 ft. in length. A continuous line of planks was set on edge to form the front and back of the concrete curb

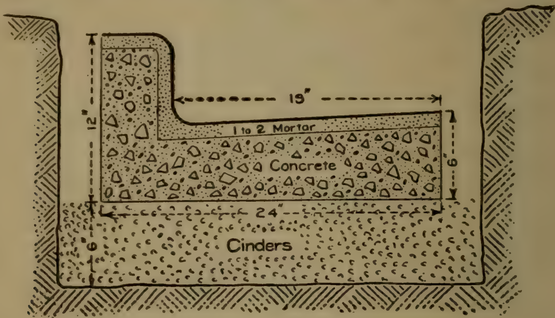


FIG. 7A.

and gutter; and wood partitions staked into place, were used. The cost of the work was as follows:

Cost of Concrete Curb and Gutter.

Item.	No. of men.	Lin. ft. per day.	Total wages.	Cost per 100 ft.
Opening trench, 18 x 30-in.........	2	144	$3.50	$2.43
Placing and tamping cinders.......	2	850	8.50	1.00
Setting forms:				
Boss setter.......................	1	....	3.00	....
Assistant setter..................	1	....	2.00	....
Laborer...........................	1	....	1.75	....
Total setting forms............	3	400	$6.75	$1.69
Mixing and placing concrete:				
Clamp man.........................	1	....	$1.75	....
Wheelers..........................	3	....	5.25	....
Mixing concrete...................	4	....	7.00	....
Mixing finishing coat.............	2	....	3.50	....
Tampers...........................	1	....	1.75	....
Finishing:				
Foreman and boss finisher.......	1	....	4.00	....
Assistant finisher................	1	....	3.00	....
Water boy.........................	1	....	.50	....
Total making concrete........	14	350	$26.75	$7.64
Total for labor per 100 ft..............................				$12.76

Materials for 100 lin. ft.:	Quantity.	Price.	
Portland cement.....	8⅓ bbls.	$1.85	$15.42
Cinders................................	7.5 yds.	.50	3.75
Gravel.................................	2.5 "	1.00	2.50
Broken stone...........................	2.5 "	1.40	3.50
Sand...................................	1.0	1.00	1.00
Total for material per 100 ft..............................			$26.17
Total for material and labor per 100 ft..................			$38.93

This is the total cost, exclusive of lumber, tools, interest, profits, etc., and it is practically 40 cts. per lin. ft.

In 100 lin. ft. of curb and gutter there were 4.6 cu. yds. of concrete and mortar facing, 4 cu. yds. of which were concrete; hence the 9 men in the concrete gang laid 14 cu. yds. of concrete per day, whereas the 4 men mixing and placing the mortar finishing laid only 2½ cu. yds. of mortar per day, assuming that the mortar finishing averaged just 1 in. thick. Since these 4 men (2 mixers and 2 finishers) received $10.50 a day, it cost more than $4 per cu. yd. to mix and place the 1:2 mortar, as compared with $1.41 per cu. yd. for mixing and placing the concrete. The concrete was built in alternate sections 7 ft. long. The 3 men placing forms averaged 400 lin. ft. a day, so that the cost of placing the forms was $1 per cu. yd. of concrete. The 2 men placing and tamping cinders averaged 6 cu. yds. of cinders per day, or 8 cu. yds. per man. This curb and gutter was built by contract at 45 cts. per lin. ft.

For several jobs, in which a curb and gutter essentially the same as shown in Fig. 7A was built, my records show a general correspondence with the above given data of Mr. Apple. Our work was done with smaller gangs, 1 mason and 2 laborers being the ordinary gang. Such a gang would lay 80 to 100 lin. ft. of curb and gutter per 10-hr. day, at the following cost:

1 mason at $2.50	$2.50
2 laborers at $1.50	3.00
Total	$5.50

This made a cost of 5½ to 7 cts. per lin. ft. for labor, and it did not include the cost of digging a trench to receive the curb and gutter.

Cost of Laying Stone Curbs.—After the trench has been dug and foundation prepared, a mason and a helper will lay 225 lin. ft. of stone curb in 10 hrs. If the mason receives 35 cts. per hr., and his helper receives 20 cts. per hr., the placing of the curb costs 2½ cts. per lin. ft. This cost is based upon the work of laying several thousand feet of dressed Medina sandstone curb, 24 ins. deep, and does not include any dressing of the stone. The men were not very efficient.

SECTION V.

COST OF STONE MASONRY.

Definitions.—*Abutment,* the foundation or substructure of a bridge. Abutments are built on the banks of a stream; piers are built in the stream itself.

Apron, a covering over the earth or rock below the spillway of a dam.

Arch culvert, a culvert with an arched roof.

Ashlar, first-class squared stone masonry dressed so that its joints do not much exceed ½-in. in thickness.

Back, the rear face of a wall.

Backing, the rough backing masonry of a wall faced with a higher class of masonry. The earth deposited back of a wall or arch is sometimes miscalled backing instead of back-filling or lining.

Barrel, the under surface of an arch. See Soffit.

Bat, a part of a brick or stone.

Batter, the backward slope of the face of a wall. A 1-in. batter means that the face of the wall departs from a plumb line at the rate of 1 in. in every foot of rise.

Beds, or bed joints, the horizontal joints of masonry. See also "Natural bed."

Belt course, a projecting course of masonry immediately under the coping; a belt course is often called a corbel course. Its object is to give a better appearance to a wall.

Bench wall, the wall or abutment supporting an arch.

Blind header, a header that extends only a short distance back into a wall instead of extending to the full depth specified; blind headers are also called "bob-tails."

Bond, the arrangement of stones so as to overlap or "break joints."

Box culvert, a culvert having a waterway of rectangular cross-section.

Breast wall, a wall built against the face of an excavation to prevent its caving down; also called a face wall.

Bridge seat, see Pedestal.

Bulkhead, a head wall at the end of a culvert, and perpendicular to the axis of the culvert; see head wall.

Bush hammer, to dress stone with a hammer having a number of pyramidal cutting teeth on its striking face.

Buttress, a vertical piece of masonry projecting from the face of a retaining wall to strengthen it.

Centers, the temporary structure that supports an arch during its construction.

Chisel draft, a narrow plane surface cut with a pitching chisel along the outer edges of the face of an ashlar stone.

Classes, different kinds of masonry specified, usually, first, second and third class; the first class being the most expensive. What is "first class" according to one engineer may be "second class" according to another.

Closer, a narrow stone used to finish a course of masonry.

Coping, the top course of stones on a wall, usually made of large flat stones which are laid so as to project a few inches over the face of the wall. A projecting coping relieves the wall of a "bobtailed" appearance.

Course, a horizontal layer or tier of stones. "Coursed masonry" is built up in courses.

Cover-stones, the flat stones forming the roof of a box culvert.

Cramp, a bar of metal having the two ends bent at right angles to the bar for insertion into holes drilled in adjoining blocks of stone.

Crandall, a stone dressing hammer, consisting of a steel bar with a slot in one end holding 10 double-headed points of steel (¼-in. square × 9 ins. long).

Crown, the top of an arch at its highest point.

Cull, a rejected stone or brick.

Culvert, a waterway under a road, canal or railroad embankment.

Cut-stone, a stone that is carefully "dressed" or shaped with tools.

Cut-water, the upper wedge-shaped end of a bridge pier.

Cyclopean masonry, masonry made of huge stones.

Damp-course, a waterproofed course or bed joint in a wall, usually just above the surface of the ground; its purpose

being to prevent the rise of water in the pores of the stone and mortar due to capillary action.

Depth, the width of a stone measured perpendicularly to the face of the wall; the distance that a face stone extends into the wall.

Dimension stone, stone dressed to exactly specified dimensions.

Dirt wall, see "mud wall."

Dog holes, shallow holes drilled in a stone to afford a bite for the "dogs," or hooks, used in lifting the stone with a derrick.

Dowel, a short steel pin inserted part way into the adjoining faces of two blocks of stone.

Draft line, see "chisel draft."

Dress, to cut or shape a stone with tools.

Drove, dressed on the face so as to have a series of small parallel ridges and valleys.

Dry wall, a stone wall built without mortar.

Efflorescence, a white crust that often forms on the face of masonry, due to the leaching of soluble salts out of the mortar; often called "whitewash."

Extrados, the curve that bounds the outer extremities of the joints between the arch stones, or voussoirs.

Face, the front surface of a wall.

Face stones, the stones forming the front of a wall.

Face-wall, see "breast wall."

Footing courses, the bottom or foundation courses, which usually project beyond the "neat work" of an abutment.

Frost batter, a batter occasionally given to the rear of a wall near its top to prevent the dislocation of the top course of stones upon the formation of frost in the ground.

Full-centered, an arch that is a full semi-circle, or half circle.

Groin, the curved intersection of two arches meeting at an angle.

Grout, a thin watery mortar which is poured into the joints after the stones have been laid.

Haunch, the part of an arch between the crown and the skewback.

Header, a stone laid with its longest dimension perpendicular to the face of the wall.

Head wall, an end wall, or bulkhead, of a culvert.

Hollow quoin, the vertical semi-circular groove in the masonry into which fits the "quoin post," or hinge post, of a canal lock gate.

Intrados, the inner curve of an arch.

Joint, the mortar filling between adjacent stones; sometimes the word joint is used to denote the vertical joints only, in distinction from the "beds" or bed joints.

Keystone, the center stone at the crown of an arch.

Lagging, the sheeting plank placed upon the ribs of arch centers.

Length, the longest dimension of a stone.

Lewis hole, a wedge-shaped hole in a block of stone, made for the purpose of lifting the block by the aid of a lewis.

Lining, the gravel or broken stone filling back of a slope wall or retaining wall, for the purpose of drainage and to protect the earth from wash.

Mortar, a mixture of sand with cement (or lime) and water. A 1 : 2 (one to two) mortar contains 1 part cement and 2 parts sand.

Mud-wall, a small parapet or retaining wall built on top of a bridge abutment to prevent the earth back-fill from sliding or washing down upon the coping.

Natural bed, a laminated or stratified stone is laid in its "natural bed," or "quarry bed," when its laminations are horizontal or perpendicular to the load that they carry. Granite has no "natural bed."

Neat mortar, mortar made without sand.

Neat work, that part of an abutment above the footing courses, which is generally equivalent to saying, that part above the surface of the ground or water.

Nigged, hewed with a pick.

Niggerheads, rounded cobble stones.

Parapet, the "mud-wall" of a bridge abutment; the "bulk head" of a culvert; the spandrel wall at each end of an arch bridge or culvert, but more properly the extension of the spandrel wall above the crown of the arch; a low guard wall rising above the surface of a roadway or walk to prevent pedestrians or vehicles from leaving the roadway or walk.

Patent hammer, a double-faced hammer so formed as to hold at each face a set of wide thin chisels for giving a finish to a stone surface.

Pedestals, or pedestal blocks, are stone blocks on top of an abutment coping; the pedestal blocks receive the weight of the bridge, and are often called "bridge seats;" the term pedestal is also applied to a small masonry pier upon which the post or sill of a trestle rests.

Perch, 16½ cu. ft. in most parts of the U. S.; in some places 22 cu. ft.; and rarely 24¾, which was the old-fashioned perch.

Pier, a masonry structure built in a river to support a bridge: a column of masonry supporting two consecutive arches. See abutment.

Pilaster, a square pillar projecting from the face of a wall to the extent of one-quarter to one-third its breadth.

Pitch-line, a well defined, straight line cut along the edge of a quarry-faced stone, but not as wide as a chisel draft.

Pitched-face, a face roughly dressed with a pitching chisel.

Plug and feathered, split with plug and feathers; the plug being a small wedge of steel driven between two pieces of half-round steel, called feathers, which bear against the sides of the drill hole.

Pointing, a superior class of mortar used to fill the joints in the face of a masonry wall for a depth of 1 to 3 ins.

Quarry faced, a rough face of stone, only the larger projections having been knocked off with a hammer.

Quoin, see "hollow quoin."

Raising stone, see pedestal.

Ramp wall, the wing of an abutment, often called a ramp.

Random, not coursed.

Ranged, laid in a course of the same thickness for its full length; broken ranged masonry is laid in courses not of uniform thickness throughout each course.

Retaining wall, a wall that receives the horizontal thrust of earth back of it; on canal work such walls are called "vertical walls" to distinguish them from slope walls.

Ring-stones, the voussoirs that form the end faces of an arch, as distinguished from the "sheeting stones" that form the body of the arch.

Rip-rap, large stones thrown in at random to protect earth from scour by currents or waves; occasionally called "random stones."

Rise, the thickness (or vertical height) of a stone, measured from its lower bed to its upper bed. Do not confuse

the "rise" with the "depth." The rise of an arch is the vertical distance from the spring line to the under face of the keystone.

Rock-faced, see "quarry-faced."

Rock-fill dam, a dam made of dry masonry; a rubble dam in which no mortar is used.

Rubble, masonry made of stones that have not been dressed, or if dressed at all, have been only roughly shaped with a hammer, or "scabbled."

Scabbled, hammer dressed.

Sheeting, the stones forming an arch. See ring-stones.

Skew arch, an arch the plane of whose ring-stone faces forms an angle of less than 90° with the axis of the barrel. If the sheeting stones are all cut skewed, the arch is a "true skew;" but if only the faces of the ring-stones are cut on a skew, while all the other sheeting stones are cut with end joints perpendicular to the bed joints, the arch is called a "false skew."

Skewbacks, the course of stones against which the springer stones of an arch abut.

Slope wall, a pavement of scabbled stones laid upon an earth slope to protect it from wash. If the stones are not scabbled, the terms rip-rap, or hand laid rip-rap, are more appropriate.

Soffit, the under surface of an arch.

Span, the shortest distance between the spring lines of an arch.

Spandrel, the triangular area bounded by the extrados of an arch, a horizontal line tangent to the extrados at the crown and a vertical line through the springing. A spandrel wall is a wall built on the extrados and filling the spandrel area; it is often miscalled a parapet wall. Spandrel filling is the earth filling between the spandrel walls.

Spall, a fragment of stone, or stone chip.

Springers, the lowest course of arch stones, the course resting on the skewbacks.

Springing, or spring line, the inner edge of the skew-backs, or the lower edge of the springers.

Starlings, the two ends of a pier.

Stretcher, a stone laid so that its longest face forms part of the face of a wall.

Voussoir, an arch stone.

Wing, a spur wall at the end of a bridge abutment, also called a ramp.

Note: Other definitions will be found at the beginning of the section on concrete.

Percentage of Mortar in Stone Masonry.—Published tables giving the percentages of mortar in different kinds of masonry have been very misleading, not only because they have been based upon meagre data, but because the factors that cause variations in mortar percentages have not been discussed.

There are two ways of estimating the amount of cement required per cubic yard of masonry: (1) By estimating the percentage of mortar in the cubic yard of masonry, and then using a mortar table like that on page 253. (2) By tabulating the different kinds of masonry and giving the fractions of a barrel of cement required for a cubic yard of each kind of masonry, when the mortar is a 1 :2 mixture, also when it is a 1 :3 mixture—these two being the common mixtures. Each method possesses its advantages, but the first is the safest because proper allowance can be made for variations in the size of cement barrel.

A great many masonry walls consist of a "facing," or ashlar, of squared stone cut to lay close joints, and a "backing" of more or less irregular rubble stones. Obviously, if the wall is a thin one, the percentage of backing is much smaller than if the wall is thick. So that it would be desirable always to keep separate records of the amount of mortar used for the backing and for the ashlar. In practice, however, it is usually impracticable to keep separate records. The final record usually gives only the amount of cement per cubic yard of the whole wall. However, in making close estimates of probable cost it is well to keep the two classes of masonry distinct.

Knowing the average size of cut stone blocks and the thickness of joints specified, we can estimate the per cent. of mortar for the face stone with considerable accuracy. Suppose the cut stone is to be in courses 12 ins. high, and dressed to lay ½-in. joints for 12 ins. back of the face. We can assume that the length of each face stone will not be far from 1½ times its thickness, or 18 ins. in this case. Hence each cut stone will contain 1 × 1 × 1½, or 1½ cu. ft.

Each stone must have one end and one bed mortared to a thickness of ½-in., hence we have: $1 \times 1 \times (½ \div 12)$, or 0.04 cu. ft. of mortar for the end; and $1 \times 1½ \times (½ \div 12)$, or 0.06 cu. ft. of mortar for the bed; making a total of 0.1 cu. ft. of mortar for the end and bed of each stone. But as each stone contains 1.5 cu. ft., we see that $0.1 \div 1.5$ gives us 7% (nearly) of mortar for the cut stone.

Obviously the larger the individual stones the less is the percentage of mortar. Stones 18 ins. high, 30 ins. long, and dressed to lay ½-in. joints for 18 ins. back of the face, require 4½% of mortar.

The mortar required for the back of the stone is apparently omitted in applying the above method, but it is not omitted in the final account, since it is included in the rubble backing, to a consideration of which we now pass.

Rubble is a term having wide variations in meaning, but in general it may be said to apply to masonry built of undressed stones just as they come from the quarry. Now, if the quarry is limestone or sandstone yielding flat-bedded stones, the rubble may be laid with bed joints as close as the joints of well dressed granite ashlar. On the other hand, if the quarry is granite or rock that when blasted yields chunks of irregular shape, the rubble becomes a sort of giant concrete and requires a large percentage of mortar to fill its voids.

In any kind of rubble the percentage of mortar can be considerably reduced by packing spalls into the vertical joints between adjacent stones. As Portland cement mortar seldom costs less than $5 per cu. yd., and as spalls usually cost but a few cents per cu. yd., no pains should be spared to use as many spalls as the joints will hold.

If no spalls are used, and if the rubble is made of irregular stones, about 35% of the rubble masonry is mortar. If the rubble is made of flat-bedded sandstone or limestone, it may contain as low as 15% mortar, but more often will average 20 to 25%.

The following are records of the actual amounts of mortar used in different masonry structures:

(1) The Medina sandstone retaining walls on the Erie Canal averaged about 10 ft. high and were faced with hammer dressed stones and backed with flat-bedded rubble. About 22% of the wall was mortar. The mortar was

1 : 2, and it required about 0.63 bbl. cement per cu. yd. of wall. A barrel was counted as holding 3.8 cu. ft.

(2) Mr. A. J. Wiley states that in the Crow Creek Dam, near Cheyenne, Wyo., there are 14,420 cu. yds. of rubble masonry, of which 34¾% was mortar. About 80% of this mortar was 1 Portland cement to 4 sand; the rest was 1 to 3. Each barrel was counted as 4 cu. ft., and 8,844 bbls. were used, or 0.62 bbl. per cu. yd.

(3) The Cheesman Dam is of rubble, with one ashlar face, and is said to contain 28% mortar.

(4) The Cheat River Bridge, on the B. & O. R. R., near Uniontown, Pa., has five piers and two abutments. The masonry is a first-class sandstone facing with a rubble backing of heavy stones, and the mortar was 1 of Louisville (natural) cement to 2 of sand. There were 3,710 cu. yds. of masonry, which required 1,500 bbls. of cement (shipped in bags), or 0.4 bbl. per cu. yd.

(5) The masonry locks on the Great Kanawaha River, W. Va., were built of sandstone obtained at Lottes, W. Va. Face stones were cut to lay ½-in. bed-joints and 1-in. vertical joints. Backing bed-joints were 1-in. The mortar was 1 part Rosendale cement (Hoffman brand), to 2 parts sand. It required 0.36 bbl. per cu. yd. of masonry.

(6) A curved masonry dam, 82 ft. high, built at Remscheid, Germany, is made of slate having a specific gravity of 2.7. The masonry, laid in trass mortar, weighs 4,015 lbs. per cu. yd. Owing to the irregular form of the stones the mortar was 38% of the masonry.

(7). The Holyoke Dam, 30 ft. high, is of rubble masonry with a cut granite face. The mortar was 1 Portland cement to 2 sand, and it is stated that 0.87 bbl. of cement was required per cubic yard of rubble masonry.

(8) Masonry in bridge piers, at Van Buren, Arkansas River, was for the most part of white limestone. In 10 piers there were 4,500 cu. yds. of masonry, which averaged 0.57 bbl. natural cement per cu. yd. The beds and joints were 1 : 2 mortar, and a 1 : 1 grout was also used.

(9) The limestone masonry for the Sault Ste. Marie locks (U. S. Government) amounted to 80,876 cu. yds., of which 23% was cut stone, 60% backing and 17% mortar. The cut stone blocks average 1.3 cu. yds. each, and were dressed to lay ⅜-in. vertical joints for 18 ins.

back of the face, and the bed joints were dressed to ⅜-in. the full depth of the stone. In cutting the stone there was a wastage of 26½% of stone. The mortar was 1 : 1, and it required 0.29 bbl. of Portland cement per cu. yd. of cut stone, 1.21 bbls. of natural cement per cu. yd. of backing, and 0.78 bbl. per cu. yd. of the wall, including cut stone and backing. The backing stones each averaged 8 sq. ft. bed area, and no bed-joint was greater than 1 in.; and no vertical joint exceeded 4 ins., the average being 2 ins. This is remarkably close jointing for backing, and was unquestionably very expensive to secure.

(10) The Lanchensee Dam, Germany, was made of graywacke rubble (stones ⅓ to ½ cu. yd. each); 35% of the dam was mortar. A force of 45 masons, 12 helpers, 27 laborers and 4 foremen worked on the dam, and 110 men at the quarry. They averaged 120 cu. yds. of masonry per day, the best day's work being 196 cu. yds. Eight locomotive cranes running on trestles took the stone from the cars. The work was done by day labor for the German Government.

(11) The Sweetwater Dam, Cal., was built of a granitic rubble that was quarried in irregular chunks. Mortar was 1 : 3, proportioned by barrels, and it required 0.86 bbl. cement per cu. yd. of rubble masonry.

Cost of Laying Masonry.—According to the author's experience on numerous small culvert bulkheads made of limestone or sandstone rubble, one mason with a helper to mix mortar and "get stone" will lay 4 to 5 cu. yds. per 8-hr. day. If mason's wages are $3 and helper's $1.50, this makes the cost axerage $1 per cu. yd. for laying. No derrick is used in such work the stone being one-man or two-man stone. Moreover, the stone requires little or no hammer-dressing on the part of the mason.

In laying dry slope-walls (12 to 15 ins. thick) where stone of the same kind as the above is used, requiring very little hammer-dressing, a slope-wall mason will lay 5 to 7 cu. yds. per 10-hr. day, and I have had a man lay as high as 12 cu. yds. per day. One laborer to about 2 or 3 slope-wall masons is required, to furnish them with stone. A common laborer will lay about half as many yards of slope-wall stone as a skilled mason, so there is

little or no economy in using unskilled labor in laying the stone that must be laid to a line and occasionally dressed with a hammer.

On a highway arch bridge of 30-ft. span, with a barrel 20 ft. long, there were 50 cu. yds. of cut stone sheeting, 30 cu. yds. of cut stone facing in the abutments and walls, and 190 cu. yds. of limestone rubble in the abutments and walls. The masonry was laid by a mason and 3 laborers, two of the laborers operating a hand power derrick and getting stone for the mason, while the third laborer made mortar and also assisted in getting stone. This gang worked without a foreman and were very slow, since they averaged only 3 cu. yds. per 8-hr. day. With mason's wages at $3 and laborers' at $1.50, the cost of laying the masonry was $2.50 per cu. yd. This included the erecting of two small derricks on opposite sides of the stream, but did not include erecting the centers for the arch. On page 206, the cost of laying the masonry of an arch bridge, similar to this one is given in detail; it being $1.35 per cu. yd., which shows how easy it is to reduce the cost of laying where the men are better organized. The common mistake made in organizing forces for laying stone with hand operated derricks is in having too many laborers to one mason, who is unable to keep them busy.

If the mason must hammer-dress the stone to a great extent, as is often required by inspectors on granite rubble arches, the cost of laying (including this hammer dressing) may amount to $3.50 per cu. yd. It is difficult to be definite in the matter of costs of hammer-dressed granite rubble, because inspectors vary so extremely in their interpretation of specifications. If no hammer-dressing is required (and none should be required for backing laid in cement mortar), the cost of laying granite rubble need not exceed the cost of laying limestone or sandstone rubble, say $1 per cu. yd., wages being as above given.

In tearing down and relaying an old masonry retaining wall (9 ft. high), the author employed 16 laborers and 2 masons under a foreman. A stiff-leg derrick having 30-ft. boom, and operated by hand, was used to handle the heaviest stones. Much of the backing was laid by hand by the laborers. This gang averaged 36 cu. yds. of masonry laid per 10-hr. day, at a cost of $30, exclusive of foreman's

wages, or less than 85 cts. per cu. yd. It cost 75 cts. per cu. yd. to tear down the wall before relaying it.

For laying any considerable quantity of masonry, never use a hand-operated derrick. A horse-whim forms cheaper power than two men on a winch. But in either case the lost time of swinging, or slewing, the boom can not be avoided. The men (usually two) who swing the boom are called "tag men," because they pull the boom back and forth with "tag ropes." The wages of these men form a surprisingly large part of the cost of laying stone where a derrick is used which is not provided with a "bull-wheel" for swinging the boom. The engineman controls the swinging of the boom where a bull-wheel is used, and can make a swing of 90° in 15 to 20 seconds.

To show how rapidly stone may be handled with a 60-ft. boom derrick, the following record will serve:

	Seconds.
Hooking on to skip	35
Swinging boom 90°	20
Dumping skip	15
Swinging back 90°	20
Total	90

This is equivalent to 400 skip loads in 10 hrs.; and, were the material supplied and removed fast enough, the derrick could readily maintain this output for 10 hrs., handling 1 cu. yd. of rubble in each skip load. Obviously in masonry work, where a bull-wheel derrick is used, the limiting factor is the amount of stone the masons can handle per day. Much of the derrick time is spent in the puttering work necessary in carefully placing large stones in the wall. Now, where tag-rope men are used instead of a bull-wheel, practically all their time is wasted, as they spend so little of the day doing active work.

Further data on the cost of laying masonry will be found on subsequent pages.

Estimating the Cost of Stone Dressing.—Stone may be divided into two classes: (1) Stone stratified in beds of a thickness not much exceeding 30 ins.; and (2) stone that is either unstratified, or occurs in beds of such thick-

ness that the blocks must be split with plugs and feathers to secure sizes which can be handled with a derrick.

Many sandstones and limestones occur in thin strata or layers, and, after the use of a little black power to "shake up" the ledge, it is possible to quarry blocks with wedges and bars. These blocks will often be as smooth as a floor on the bed-joints, but may be quite irregular on the vertical joints. However, either by hammering, or by plug and feathering, the vertical joints can be squared up at slight expense ready for further dressing if required by the specifications. On the other hand, all granites and many thick-bedded limestones and sandstones, break out in such irregular shapes that it often happens that every face must be plug and feathered before the block is roughly squared up ready to be dressed by the stone cutters. Obviously the dressing of the beds of such stones is far more expensive than the dressing of the beds of smoothly stratified stones.

Besides differences in hardness, we see that the shape of the stones as they come from the quarry is a very important factor in the cost of dressing.

Another factor of scarcely less importance is the size of the blocks of stone. It is generally possible to quarry granites in blocks of any desired size, the limit being fixed by the strength of the derricks and other machinery used. A very common size of granite blocks dressed ready to lay in the wall is 18 ins. rise × 40 ins. length × 24 to 30 ins. depth. And as every block of granite must be plug and feathered to size before dressing, it is just as cheap to make coursed ashlar as random range ashlar. On the other hand, stratified rocks like sandstone usually occur in layers of different thickness, and it may be impossible to secure enough stone for courses of a specified rise without wasting a large part of the quarry product. An engineer should never specify any given "rise" for the courses (except in granite), until he has examined the quarries and is sure that they will yield the product specified. But engineers often fail to do this, and the contractor must be careful not to be equally foolish in failing to examine the stone available.

Stone is often so seamy or so brittle that it can be quarried only in small chunks. Now it is obvious that

the smaller the chunk the greater the area that must be dressed per cubic yard; but how greatly this factor affects the cost of dressing is seldom considered. To illustrate, let us assume that blocks for ashlar are each 12 ins. rise × 24 ins. long × 18 ins. deep. Each block then contains 3 cu. ft., and has 6 sq. ft. of bed joints and 3 sq. ft. of end joints, or 9 sq. ft. of joints to be dressed. Let us now take an ashlar block 18 ins. rise × 36 ins. long × 24 ins. deep. This block contains 9 cu. ft., and has 12 sq. ft. of bed joints and 6 sq. ft. of end joints, or 18 sq. ft. of joints to be dressed. With the smaller block we have 9 × 9, or 81 sq. ft. of joints to be dressed for every cubic yard; whereas with the larger block we have 3 × 12, or 36 sq. ft. to be dressed for every cubic yard. In other words the cost of dressing ashlar of the 3-cu. ft. blocks is more than twice as expensive per cubic yard as the cost of dressing the 9-cu. ft. blocks.

It is apparent, therefore, that all records of the cost of dressing stone should be expressed in terms of the square feet actually dressed, and then the data can be applied to blocks of any given size to obtain the cost of dressing per cubic yard. This method of estimating costs will often lead a contractor to import his stone a long distance by rail rather than attempt to dress the small sized stones from local quarries.

It is customary among contractors and stone cutters to speak of so and so many "square feet" of stone dressed per day, meaning not the number of square feet of beds and joints dressed, but the square feet of "face." For example a stone is 1½ ft. rise × 3 ft. long × 2 ft. deep. This stone when laid lengthwise in the face of a wall will show a face area of 4½ sq. ft., and the stone cutter is said to have dressed 4½ sq ft. As a matter of fact he has dressed 12 sq. ft. of bed joints, and 6 sq. ft. of end joints, beside plugging off or hammering the face of the stone, and cutting the drafts if specified. In my early work I was misled by this method of estimating stone dressing in terms of the square feet of face. It is a method that should be abandoned.

Data of the actual cost of stone dressing will be given in subsequent pages.

Data on Stone Sawing.—There is little on this subject

in print, but in almost any large city stone saws may be seen at work, and a rough estimate can be made of the cost of stone sawing. To tell how many inches deep a saw cuts in a day, examine a slab of stone newly cut in the yard. It will be noted that there are rust lines on the face of the slab. The distance between these lines indicates the depth cut in a day, for when the saws are idle at night, the rust forms.

For cutting stone into thin slabs, it is common practice to run two "gangs" of saws, of 15 saws in a "gang" driven by a small engine. As nearly as I have been able to estimate by observation and inquiry, the daily cost of operating a "two-gang" plant is as follows per 9-hr. day in New York City:

1 gangman	$4.00
1 helper	3.00
2 cu. yds. sand, at $3	6.00
½ ton coal, at $6	3.00
Total per day	$16.00

Working in Tennessee marble each saw cuts about 6 ins. deep per day, therefore, if the block is 6 ft. long, the 30 saws cut 90 sq. ft. per day of 9 hrs. The cost of sawing slabs, therefore, approximates 17 cts. per sq. ft. The saw cuts a kerf ⅛-in. wide.

I am told that with wages of polisher at $3.50, slabs can be polished by hand at 6 cts. per sq. ft.; but where the polishing is done by machine the cost is about 2½ cts. per sq. ft.

Wages of stone yard men in New York City are about a third higher than in most other American cities.

Mr. R. J. Cooke states that the rates of sawing different kinds of stone are as follows:

	Depth cut in 10 hrs., ins.
Granite, Addison, Me. (shot)	10
Granite, Chester, Mass. (sand)	12
Granite, Red Beach, Me. (shot)	7½
Bluestone, Hudson River (sand)	8
Marble, Carara, Italy (sand)	15
Marble, Tennessee (sand)	9
Marble, Tate, Ga. (sand)	6

	Depth cut in 10 hrs., ins.
Marble, Tate, Ga. (sand)	12
Marble, Gouverneur, N. Y. (sand)	12
Marble, W. Rutland, Vt. (sand)	20
Marble, Proctor, Vt. (sand)	15
Limestone, New Point, Ind. (sand)	10
Limestone, New Point, Ind. (sand)	15
Oolitic limestone, Bedford, Ind. (sand)	40
Oolitic limestone, Bedford, Ind. (sand)	70
Magnesian limestone, Lemont, Ill. (sand)	36
Sandstone, N. Amherst, O. (sand)	40
Sandstone, Clarksville, O. (sand)	36
Brownstone, Portland, Conn. (shot)	20
Brownstone, Hummelston, Pa. (shot)	25

The Young & Farrell Diamond Stone Sawing Co., of Chicago, classifies stone into soft, medium and hard; soft includes sandstones; medium includes limestones, and hard includes marbles and granites. They say (1890) the cost of sawing per sq. ft. is: Soft, 8 to 10 cts.; medium, 13 to 17 cts.; hard, 25 to 30 cts.; all on the basis of 4-in. sawing or two cuts to the cubic foot. With wages of stone cutters at 50 cts. an hour, the cost of hand dressing the same classes of stones is given as follows per square foot: Soft, 25 to 30 cts.; medium, 40 to 45 cts.; and hard, 75 to 80 cts.; all clear face work.

Cost of Stone Dressing.—In addition to the data just given, The Syenite Granite Co., of Graniteville, Mo., say (1890) that the cost of hand dressing 36,000 cu. ft. of granite to ½-in. joints was 20 cts. per sq. ft., not including blacksmithing, handling, etc., which was 6 cts. more per sq. ft. This stone was granite cut to lay in 24 to 30-in. courses for the Merchants' Bridge, St. Louis, and it was delivered for $1.15 per cu. ft.

The Kankakee Stone & Lime Co. say (1890) that, with wages at $3 a day, the cost of dressing limestone (bush-hammered or drove-work) is 25 cts. per sq. ft.

Cost of Cutting Limestone and Sandstone.—In dressing Medina sandstone, a stone cutter will dress enough stone in 9 hrs. to lay 12 sq. ft. of face in a wall having courses that average 15 ins. rise, which is equivalent to about 0.9 cu. yd. of face stone per day, or 30 sq. ft. of

beds and joints cut to lay ½-in. joints for at least 12 ins. back of the face. The face is rock-faced, and is plugged off by the stone cutter.

In dressing limestone for arch sheeting, the author made the mistake of using a quarry whose product was all small and gnarled stones. Each stone after dressing averaged only 11 ins. thick, 22 ins. long, and 18 ins. deep, or about 0.1 cu. yd. per stone, so that to secure 1 cu. yd. of this cut-stone required the dressing of 80 sq. ft. of beds and joints! Each stone cutter averaged 36 sq. ft of beds and joints (dressed to lay ½-in.) per 9-hr. day, or 1 cu. yd. in 2¼ days. These cutters received 40 cts. per hr.

Cost of Sandstone Bridge Piers.—The cost of cutting 246 cu. yds. sandstone to ½-in. joints for bridge piers was $2.65 per cu. yd.; the cutting of the stones for the nose of the pier cost $3 per cu. yd. The wages of cutters were 38 cts. per hr.

The cost of loading the stone, train service, sand, cement and laying the masonry was $3.60 per cu. yd. About ⅓ bbl. of Portland cement costing $2.40 per bbl. was used per cu. yd. of masonry. The cost of quarrying the stone was $1.65 per cu. yd. The total cost of the pier masonry was $9 per cu. yd. For the foregoing data I am indebted to Mr. C. R. Nehr, M. Am. Soc. C. E.

Cost of Cutting Granite for a Dam.—In building a dam in the northern part of New York State, the author used a granitic rock. The face stones were cut to lay in courses with beds and joints ⅝-in. thick. Each cut stone was quarry-faced and averaged 1½ ft. rise × 3 ft. long × 2 ft. deep, or about ⅓ cu. yd. A stone cutter averaged one such stone per 8-hr. day, or 18 sq. ft. of beds and end joints dressed per day. A blacksmith, at $2.50, and a helper, at $1.50, sharpened the points and plug drills for 8 stone cutters. The cost of cutting this face stone was as follows:

	Per cu. yd.
Stone cutters at $4 per 8 hrs.	$12.00
Blacksmithing	1.20
Labor bankering stones and plugging off faces	1.80
Sheds and tools	0.80
Superintendence	1.20
Total	$17.00

On a small portion of the work the stone was dressed to lay ¼-in. joints, which added $6 per cu. yd. to the cost.

Cost of Cutting Granite, New York City.—In Trans. Am. Soc. C. E., 1875, Mr. Wm. W. Maclay gives the cost of cutting 2,065 cu. yds. of granite by a force of 40 stone cutters working for the New York Department of Docks, during 1873 to 1875. The working day was 8 hrs. The following table gives the average day's work of a stone cutter working for the Dock Department as compared with work done for contractors in New York:

Cutting Granite.	Sq. ft. per 8-hr. day — For Dock Dept.	For Contractors.
Dressing beds and joints (¼ in.)	13.5	16.0
Pointed work with 1½ in. chisel draft all around	8.5	10.0
Pean-hammered	6.0	7.25
6-cut patent hammered	5.25	6.15
8-cut patent hammered	4.25	5.00

It will be noted that the men working for the Dock Department did about 15% less work daily than is said to have been the average under contractors.

In doing this dock work there were 1,524 cu. yds. of dimension stones cut into headers and stretchers. The headers averaged 2 ft. on the face by 3 ft. deep; and the stretchers averaged 6 ft. long on the face by 2 ft. deep; the rise being 20, 22 and 26 ins. for the different courses. The stones were cut to lay ¼-in. beds and joints, the faces being pointed work with a 1½-in. chisel draft all around. The cost of this cutting was as follows:

	Per cu. yd.	Per cent.
Cutting (4.53 days)	$13.22	48%
Labor rolling stones	8.26	30%
Sharpening tools	4.13	15%
Superintendence	1.38	5%
New tools and timber for rolling stones	0.28	1%
Interest on sheds, derrick, and railroad	0.28	1%
Total	$27.55	100%

In addition to this work there were 310 cu. yds. of coping cut to lay ¼-in. joints, pointed on the face and with a chisel draft, 8-cut patent-hammered on the top, and with a round of 3½-in. radius. The coping stones were 8 ft. long, 4 ft. wide, and 2½ ft. rise. The cost of cutting this coping was as follows:

	Per cu. yd.	Per cent.
Cutting (6.26 days)	$18.27	48%
Labor rolling stones	11.42	30%
Sharpening tools	5.71	15%
Superintendence	1.90	5%
New tools and timber	0.38	1%
Interest on sheds, etc.	0.38	1%
Total	$38.06	100%

It would appear from the above that the stone cutters received $3 for 8 hrs., but Mr. Maclay states that the pay was $4 for 8 hrs. If so there is some error in the other items, which I have calculated from the percentages given by him. It is difficult to understand how the "labor of rolling stones" could have been 30% of the total cost of cutting, unless the laborers assisted in plug and feathering the stones preparatory to cutting. The cost of tool sharpening (15%) was also very high. Certainly these two items were much higher than they would have been under a contractor.

Mr. J. J. R. Croes states that in cutting granite for the gate-houses of the Croton Reservoir at 86th St., New York, in 1861-2, the least day's work was fixed at 15 sq. ft. of beds and joints. This included the cutting of a chisel draft around the face of the stone, the cost of which was about one-fourth as much as cutting a square foot of joint, making the actual least day's work equivalent to 17.7 sq. ft. of beds and joints cut. With wages of stone cutters assumed at $3 per day, from the percentages given by Mr. Croes, I have calculated the cost of cutting to have been as follows per square foot:

	Per sq. ft.
Cutting (15 sq. ft. per day)	$0.200
Sharpening tools	0.022
Labor moving stone in yards	0.020
Drillers plugging off rough faces	0.008
Superintendence	0.016
Sheds and tools	0.014
Total	$0.280

The cost of all the items other than the wages of stone cutters was 40% of the wages of the stone cutters, or 8 cts. per sq. ft.

Cost of Quarrying, Cutting and Laying Granite.—In Trans. Am. Soc. C. E., 1875, Mr. J. J. R. Croes gives the following data relative to work done on the Boyd's Corner Dam, near New York City:

The stone is a gneiss that is about as difficult to quarry as granite. The face stone for the dam average 1.8 ft. rise, 3.6 ft. long and 2.7 ft. deep, and were cut to lay ¾-in. joints. In quarrying the dimension stone, plug and feathers were used to split the stone to size ready for cutting. The cost of quarrying and plug and feathering 4,000 cu. yds. of dimension stone ready for cutting was as follows:

	Days (10-hr.) per cu. yd.	Cost per cu. yd.
Foreman, at $3	0.114	$0.34
Drillers, at $2	0.917	1.84
Laborers, at $1.50	0.429	0.65
Blacksmiths, at $2.50	0.102	0.25
Tool boys, at $0.50	0.108	0.05
Labor loading teams, at $1.50	0.284	0.42
Total (not including explosives and teaming)		$3.55

The work was done by contract in 1867-8. The rates of wages were not given by Mr. Croes, but Mr. John B. McDonald has been kind enough to give me most of the rates of wages as nearly as he can remember. The length of haul from quarry to stone yard was about a mile, and Mr. McDonald states that oxen were used. The cost of "teams" is given by Mr. Croes, as 0.62 team day per cu. yd., which indicates that a good deal of stone boat work was done, or else that there is an error in this item.

The cost of quarrying 3,400 cu. yds. of rubble stone for this same dam was as follows:

	Days per cu. yd.	Cost per cu. yd.
Foremen, at $3	0.041	$0.12
Drillers, at $2	0.339	0.68
Laborers, at $1.50	0.140	0.21
Blacksmiths, at $2.50	0.036	0.09
Tool boy, at $0.50	0.035	0.02

	Days per cu. yd.	Cost per cu. yd.
Labor, loading teams, at $1.50........	0.077	$0.12
Teams, at $4	0.141	0.56
Total labor		$1.80

It is presumable that both the dimension stone and the rubble stone were measured in the dam.

The masonry was called "rubble range," a term that deceived most of the contractors, for the specifications in fact called for stones cut to lay in courses with ¾-in. *bed* joints. During 3½ years of work there were 5,200 cu. yds. of this "rubble range" cut, requiring the dressing of 6,373 sq. ft. Each stone averaged 1.8 ft. rise, 3.6 ft. long, and 2.7 ft. deep., or 0.65 cu. yd. per stone. Each stone cutter averaged 18.7 sq. ft. of bed joints dressed per day, so that it took 1.57 days to dress each cubic yard of "rubble range" stone.

The ashlar stones were called "dimension cut-stone masonry" and were cut to lay ¼-in. joints both on bed and end joints, and the faces were pean hammered. The lowest bid on this ashlar was $30 per cu. yd., but another contractor, who had previously done the same kind of work, bid $60 per cu. yd.

It took 9 days' work of a stone cutter to dress each cubic yard of this ashlar.

The coping was laid in two courses; one course of stones 12-in. rise, 30-in. bed, and 3½-ft. length; the other course, 24-in. rise, 48-in. bed, and 2½-ft. length. The top was pean hammered, and the face was left rough with a chisel draft around it. The beds and joints were cut to lay ¼-in. It took a stone cutter 6.1 days to dress each cubic yard of this ashlar.

The cost of laying the masonry in the dam was as follows, wages being assumed to be approximately what they are now (not what they were in 1875):

	Cost per cu. yd.			
	A	B	C	D
Mason at $3.00......................	$0.36	$0.36	$0.25	$0.32
Laborers at $1.50....................	0.28	0.28	0.22	0.28
Mortar mixers at $1.50..............	0.15	0.12	0.11	0.15
Derrick and carmen at $1.50........	0.49	0.51	0.36	0.39
Engine at $4.00......................	.....	.....	0.18	0.20
Teams from yard at $3.50............	0.35	0.20	0.20	0.39
Laborers loading teams at $1.50....	0.28	0.33	0.33	0.13
Total..........................	$1.91	$1.80	$1.65	$1.81

Columns A and B relate to work done in 1868 and 1869 when the stone was hoisted by hand; A was a lift of 5 ft., B was a lift of 10 to 20 ft. Columns C and D relate to work done in 1869 and 1870, when the hoisting was done by engines; C being a lift of 20 to 30 ft.; D being a lift of 30 to 50 ft. It will be noted that each mason laid from 8½ to 12½ cu. yds. per day. Each engine apparently served two masons, but it is not stated whether each mason had a separate derrick or both worked with one derrick.

The stones were laid in inclined or sloping courses, which made it hard to keep them in place as a rap of a hammer would cause sliding.

It will be noted that the cost of loading and hauling the stone from the stone yard to the dam is included in the above costs of laying. This cost of loading and hauling is not properly a part of the cost of laying.

The mortar was a 1 : 2 mixture, natural cement, and it required 0.3 bbl. of cement, 0.093 cu. yd. sand, and 0.89 cu. yd. of stone per cu. yd. of dam masonry. In other words, only 11% of the masonry was mortar!

Cost of Plug Drilling by Hand.—By timing a number of masons at work splitting granite blocks 24 to 30 ins. thick, I found that each man drilled each hole (⅝-in. diam. × 2½ ins. deep) in a trifle less than 5 mins., by striking about 200 blows. It took about 1 min. for placing and striking each set of plug and feathers. A block 30 ins. long, with four plug holes, was drilled and split with the plugs and feathers in 24 mins., on an average. At this rate, a good workman can drill and plug 80 holes in 8 hrs., but it is not safe to count upon so large an average.

Cost of Pneumatic Plug Drilling.—For drilling plug holes in granite certainly no tool is as economic as the pneumatic plug drill. Horizontal as well as vertical holes can be rapidly drilled. The ordinary plug drill, according to the manufacturers, consumes 15 cu. ft. of free air per min. at 70 lbs. pressure. At the Wachusett Dam I found that a workman averaged one hole (⅝-in. diam. × 3 ins.) drilled in 1½ mins., including the time of shifting from hole to hole, but not including the time of driving the plugs. About 250 plug holes are counted a fair day's

work for a plug drill where the driller does not drive the plugs himself.

Cost of Quarrying Granite.—Cost data relating to the quarrying of granite dimension stone are extremely hard to secure. I have been able to find only one writer, Mr. J. J. R. Croes, who has published anything on the subject. Mr. Croes' records, together with mine, will at least form a basis for approximate estimates of cost of granite quarrying. My data apply to quarrying three-dimension stone in a sheet quarry on the coast of Maine. The total number of men engaged was, on the average: 6 enginemen, 6 steam drillers, 6 drill helpers, 3 blacksmiths, 3 helpers, 5 tool and water boys, 38 quarrymen, 47 laborers, 2 foremen and 1 superintendent. This force quarried and loaded on boats about 1,400 cu. yds. of rough granite blocks. The stone was loaded by derricks onto cars from which it was unloaded into boats ready for shipment. The following cost includes everything except interest and depreciation of plant, and development expenses:

	Cost per cu. yd.
Enginemen, at $2 a day (of 9 hrs.)	$0.20
Steam drillers, at $2.00	0.20
Drill helpers, at $1.50	0.15
Blacksmiths, at $2.75	0.14
Blk. helpers, at $1.75	0.09
Tool and waterboys, at $1	0.16
Quarrymen, at $1.75	1.09
Laborers, at $1.50	1.15
Foremen, at $3.00	0.15
Superintendent, at $8	0.20
Coal, at $5 ton	0.45
Explosives	0.25
Other supplies	0.30
Total	$4.53

On the best month's work, when a larger force was being operated, the cost of all labor, superintendence and supplies, was reduced to a little below $4 per cu. yd.; but the above $4.50 per cu. yd., may be taken as a fair average of several months' work. To this should be added the

charges for plant rental, quarry rental (if any), stripping (if any), and freight charges to destination. The freight rate by boat from Maine to New York is about $1 a ton, but as rough granite blocks are always measured on their least dimensions, the freight charges when $1 per ton amount to about $2.70 per cu. yd., of three-dimension stone in the rough. The explosives used were black powder, costing $2.25 a keg (25 lbs.), and dynamite for channeling, costing 15 cts. a lb. The sheet from which this granite was quarried averaged about 6½ ft. thick, and was nearly flat. The stone was loosened in long blocks by Knox blasting with black powder, and was split up into sizes by plug and feathering; both hand drills and pneumatic plug drills being used for this purpose. The stone, as before stated, was three-dimension stone. To quarry random stone (not rubble) in this quarry cost about $3.50 per cu. yd.

If granite is blasted out in all shapes and sizes, to be used for rubble or for concrete, the cost of quarrying is far less than the above and is approximately the same as quarrying trap rock.

Cost of a Masonry Arch Bridge.—This arch bridge had a span of 30 ft., and its barrel was 60 ft. long. The masonry was limestone laid in Portland cement mortar. There were 365 cu. yds. of masonry distributed as follows:

	Cu. yds.
Arch sheeting	112
Bench walls (or abutments)	165
Backing above arch	17
Backing above haunch	38
Wing walls	21
Parapet walls	7
Coping	5
Total	365

The arch sheeting masonry was dressed to lay ⅝-in. joints, and the cost of these 112 cu. yds. was as follows:

	Cu. yd.
Quarrying rough blocks	$1.00
Plug and feathering into blocks	0.85
Hauling and loading onto car	0.75

	Cu. yd.
Freight	$1.05
Unloading from car and hauling 1 mile	0.70
Cutting	4.55
Laying	1.35
Mortar	1.50
Centers	2.20
Total	$13.95

This sheeting was cut to lay an arch 18 ins. thick each block averaging 12 × 18 × 28 ins. in size, or about ⅛ cu. yd. The blocks were small, but the quarry did not yield large material. Quarrymen were paid 30 cts. per hr. and helpers 17½ cts. per hr. The unloading from cars onto wagons cost 35 cts. per cu. yd., wages being 15 cts. per hr.; and the hauling 1 mile cost 35 cts. per cu. yd., teams being 40 cts. per hr.

The stone cutters were paid 35 cts. per hr., and their work cost $4.25 per cu. yd.; the sharpening of cutters' tools cost 15 cts. more per cu. yd.; and the help of laborers occasionally in bunkering a stone cost another 15 cts. per cu. yd.; making a total of $4.55 for cutting the stone after it had been plug and feathered roughly into blocks. The small size of the blocks made this cost high.

The stone was laid by a hand-power derrick, the cost of laying being in detail as follows:

	Per cu. yd.
Masons at 30 cts. per hr.	$0.80
Helpers at 15 cts. per hr.	0.45
Team on stone boat, 40 cts. per hr.	0.10
Total cost of laying	$1.35

Each mason had 1¼ helpers and laid 3 cu. yds. in 8 hrs. This was the average of all the 365 cu. yds. of masonry; the cost of laying each kind was not kept separately.

The mortar was 1 : 3 Portland cement, allowing 4.5 cu. ft. per bbl.; it took 2 bbls. of cement and 0.9 cu. yd. sand to make 1 cu. yd. mortar; and the cost of these materials was $4.50 per cu. yd. of mortar. It took ⅓ cu. yd. of mortar for each of the 365 cu. yds. of masonry; no attempt was made to determine the amount of mortar for each kind of masonry.

The cost of the ashlar facing in the abutments and wing walls was the same per cubic yard as the arch sheeting after deducting the $2.20 for centers, that is $11.75 per cu. yd.; and there were about 50 cu. yds. of this in the bridge.

The cost of the rubble backing in the abutments, haunch, etc., of which there were nearly 200 cu. yds., was as follows:

	Per cu. yd.
Rubble sandstone delivered at bridge	$1.20
⅓ cu. yd. mortar, at $4.50	1.50
Laying	1.35
Total	$4.05

This rubble was a local sandstone, but the ashlar was a limestone imported by rail.

The foregoing costs do not include foreman's salary and general expenses, which amounted to 15% of the total cost of the bridge. In addition to the 365 cu. yds. of stone masonry there were 65 cu. yds. of concrete foundations laid on a hard clay. There was no cofferdamming.

The cost of the work was higher than it would have been under a better foreman.

Cost of Centers for 30-ft. Arch.—Centers for a masonry arch of 30-ft. span and having a barrel 60 ft. long were made of hemlock. There were 21 arch ribs or centers spaced 3 ft. apart and lagged with hemlock 2 ins. thick by 6 ins. wide. Each center was made of two thicknesses of 2 × 12-in. plank cut in sections 6 ft. long and spiked together, breaking joints. The ribs were cut to the curve of the arch at a saw mill. The following was the bill of timber in each center:

	Ft. B. M.
6—2 in. x 12 in. x 12 ft. curved ribs	144
4—2 in. x 6 in. x 16 ft. ties	64
1—2 in. x 6 in. x 10 ft. splices	10
1—2 in. x 6 in. x 10 ft. post	10
2—2 in. x 6 in. x 16 ft. struts	32
Total per bent	260
22 centers at 260 ft. B. M.	5,720
Lagging 2 in. x 33 ft. x 60 ft	3,960
Total	9,680

The machine work at the mill cost $20, and the carpenter work of framing the centers was $7.75 for carpenters at 22½ cts. per hr. and $9.25 for carpenters' helpers at 15 cts. per hr., making a total of $37. This is equivalent to $6.50 per M when distributed over the 5,720 ft. B. M. in the centers. The cost of erecting the centers with the aid of a hand-power derrick together with the cost of placing the lagging was $24, all this work being done by laborers at 15 cts. per hr. This $24 distributed over all the 9,712 ft. B. M. is $2.56 per M. The cost of removing the centers after completion of the work was $10, wages being 15 cts. per hr., or $1.05 per M. The total cost of the centers was:

9,712 ft. B. M. hemlock, at $16	$155.51
132 oak wedges, at 10 cts.	13.20
230 lbs. wire nails, at 3½ cts.	8.05
Machine work at mill	20.00
Work framing centers	17.00
Work erecting centers	24.00
Work tearing down centers	10.00
Total	$247.76

It will be noted that the millwork and labor cost $71, which is equivalent to $7.30 per M distributed over the 9,712 ft. B. M. There were 112 cu. yds. of masonry in the arch alone, so that the cost of the centers distributed over the arch sheeting was $2.20 per cu. yd. But there were 250 cu. yds. of masonry, all told, in the arch, the abutments, parapet and wing walls. The short posts supporting the centers rested on hard clay.

Cost of Arch Culverts and Abutments, Erie Canal.—In 1840 contracts were let for enlarging the Erie Canal. The courts later declared the law making the appropriation unconstitutional and the N. Y. State Legislature directed that the contracts be cancelled and that contractors be paid their prospective profits. The 12 engineers in charge of the work submitted the following estimates of the actual cost. The stone in masonry was limestone from the lower Mohawk valley. Masons and stone cutters were paid $2.25 per day of 11 hrs. worked, laborers $1.

The cost of masonry in arch culverts and bridges was as follows:

Face stone:	Per cu. yd.
Quarrying, 1 cu. yd. per man day	$2.25
Cutting, 1.3 cu. yds. per man day	2.25
Laying, 0.7 cu. yd. per man day	1.25
Mortar	0.75
Total, not including hauling	$6.50

Note: The cost of quarrying includes sharpening drills, foremen, etc.

Backing (rubble):	
Quarrying, 2 cu. yds. per man day	$1.00
Laying, 1.75 cu. yds. per man day	1.00
Mortar	1.25
Total, not including hauling	$3.25

Arch sheeting:	
Quarrying, 1 cu. yd. per man day	$2.25
Cutting, 0.88 cu. yd. per man day	3.25
Laying, 0.7 cu. yd. per man day	1.25
Mortar	1.00
Total, not including hauling, or centers	$7.75

Ring and Coping:	
Quarrying, 0.6 cu. yd. per man day	$3.40
Cutting, 0.55 cu. yd. per man day	5.00
Laying, 0.58 cu. yd. per man day	3.00
Mortar	0.50
Total, not including hauling	$11.90

The cost of hauling stone 1 mile from quarry to canal was 50 cts. per cu. yd., 7 round trips being made per day by a team hauling ¾ cu. yd. of stone, as measured in the work.

The centers for arch culverts of 4 to 8-ft. span were estimated to cost 50 cts. per cu. yd. of arch masonry. For

spans of 10 to 15 ft. the centers cost 75 cts. per cu. yd. of arch masonry.

Timber stringers covered with 2 or 3-in. plank were largely used for foundations and floors of culverts. The cost of placing such timber was $4 per M.

Cost of Lock Masonry, Erie Canal.—The following is a continuation of the data just given:

The masonry for locks was dressed as follows: Cut stone face, ⅛-in. joints; hammer dressed backing, 1-in. joints. Wages were as above given.

Lock face stone:

Quarrying, 0.67 cu. yd. per man day	$3.00
Cutting, 0.50 cu. yd. per man day	5.50
Laying, 3.00 cu. yds. per man day	0.83
Mortar	0.50
Machinery	0.25
Total, not including hauling	$10.08

Lock backing (1-in. joints):

Quarrying, 1 cu. yd. per man day	$2.00
Cutting, 1.8 cu. yds. per man day	1.50
Laying, 4 cu. yds. per man day	0.62
Mortar	0.75
Machinery	0.25
Total, not including hauling	$5.12

The average cost of lock masonry, including face and backing, was $7.10 per cu. yd., exclusive of transportation which was $2.75 per cu. yd.

The cost of a masonry aqueduct consisting of masonry piers, arches and spandrels, was as follows:

To lay pier masonry:	Per day.
1 mason	$2.25
2 tenders, at $1	2.00
½ stone cutter, at $2.40	1.20
Total, 5.9 cu. yds. laid at $0.92 per cu. yd.	$5.45

To lay arch masonry:	Per day.
1 mason	$2.25
2 tenders	2.00
1 stone cutter	2.50
Total, 8.95 cu. yds. laid at $0.76 per cu. yd.	$6.75

To lay spandrel masonry:	Per day.
1 mason	$2.25
2 tenders	2.00
1¾ stone cutters	4.00
Total, 8.26 cu. yds. laid at $1 per cu. yd.	$8.25

The total cost of aqueduct masonry, per cubic yard, excluding the cost of laying just given, was as follows:

	Per cu. yd.
Quarrying	$2.25
Transportation	2.00
Cutting	2.25
Mortar	1.00
Machinery	0.25
Total, not including laying	$7.75

Approximately $0.90 per cu. yd. should be added to this $7.75 to include cost of laying the masonry.

Cost of the Sweetwater Dam.—James D. Schuyler gives the following data on the Sweetwater Dam, California: The dam is 46 ft. thick at the base, 12 ft. at the top, and 90 ft. high. It is built as an arch with a radius of 222 ft. on line of face at the top. The stone was a metamorphic (or igneous?) rock with no well-defined cleavage, breaking out in irregular masses. Its weight ranged from 175 to 200 lbs. per cu. ft. And the average weight of the masonry was estimated to be 164 lbs. per cu. ft. The mortar was a 1 : 3, proportioned by barrels, mixed in a Ransome mixer. The mixer was given 3 or 4 turns after charging it with sand and cement, then the water was admitted during the next 3 or 4 revolutions; 8 to 10 revolutions made a thorough mixture, requiring 2 to 3 mins. A tramway for delivering the mortar was carried around the

face of the dam, on a bracket trestle held by bolts driven into holes drilled in the face of the dam masonry. A grade of 3 ft. in 40 at the end of the tramway next to the mixer was sufficient to give the mortar car an impetus that would carry it to the farthest end of the dam. By using this mechanical mixer and tramway a force of 5 men and a horse did the work formerly done by 4 mortar mixers and 14 hod carriers. The box of mortar was lifted from the car by a derrick and delivered to the masons.

The stone was quarried from a cliff 100 ft. high situated 800 ft. below the dam. It was hauled in wagons rigged with platforms on a level with the rear wheels. The quarry derricks were simple shear-legs, slightly inclined. All stones smaller than 500 lbs. were loaded on stone boats 4 ft. square, made of 3-in. plank with a bottom of boiler plate and provided with chains at the corners. The shear-leg derricks were used to hoist the stone boats and deposit their loads on the wagons. Stone boats cost $30 each, and several sets of them were worn out on the job. A single stone, weighing 3 tons or more, was readily lifted by the shear-legs, and lowered upon a wagon driven underneath. All hoisting was done by horse power. Four derricks were used on the dam, masts being 30 to 38 ft. long, and booms 26 to 32 ft. A fifth derrick, with a 50-ft. mast and a 45-ft. boom, proved far more efficient than the others. The work was completed Apr. 7, 1888, after 16 mos.

The masonry was rubble throughout, amounting to 20,507 cu. yds., of which 19,269 cu. yds. were in the dam proper; 0.86 bbl. of cement was used per cubic yard of masonry.

The cost of the dam was as follows:

17,562 bbls. cement	$63,111
Hauling cement	8,614
Lumber	2,408
Iron work	4,916
Powder and miscellaneous supplies	3,230
Pipes, gates, etc.	5,152
Plant, tools, etc.	6,237
Total for materials and plant	$93,668

Labor, common and skilled	$93,591
Foremen	6,866
Teams	19,696
Engineering	10,555
Clerical work	654
Earthwork (by contract)	7,666
Miscellaneous expenses	1,377
Total for labor	$140,405
Total for materials, etc.	93,668
Grand total	$234,073

Common laborers were paid $2 to $2.50 a day; masons, $4 to $5; carpenters, $3.50 to $4; blacksmiths, $4; teams with drivers, $5; machinists, $7 to $8; foremen, $4 to $6. Workmen were scarce and independent on account of the "boom" in California. The work cost 20 to 25% more than it would have cost under normal conditions.

The itemized cost of 11,322 cu. yds. of the masonry laid from May 1 to Dec. 31, 1887, was as follows per cubic yard:

	Per cu. yd.	Percentage of total.
Quarrying stone (labor)	$0.425	4.829
Loading stone	0.523	5.933
Hauling stone	0.420	4.758
Hoisting stone	0.577	6.550
Loading and hauling sand	0.345	3.915
Cement, at $4.20 per bbl.	3.427	38.900
Mixing and delivering mortar	0.239	2.710
Masons	0.797	9.050
Helpers	0.186	2.109
Excavating foundations	0.303	3.444
Making and repairing roads	0.118	1.336
Blacksmithing (labor)	0.163	1.854
Carpentry	0.097	1.104
Rope	0.104	1.186
Tools	0.046	.524
Steel	0.014	.155
Blacksmith coal	0.009	.109

	Per cu. yd.	Percentage of total.
Blocks and sheaves	$0.011	.133
Powder	0.086	.974
Lumber	0.195	2.220
Wetting masonry	0.048	0.542
Foremen	0.332	3.774
Engineering and superintendence	0.343	3.891
Total	$8.808	100.000

Cost of a Granite Dam, Cheyenne, Wyo.—Mr. A. J. Wiley gives the following data on a dam for the Granite Springs Reservoir, Cheyenne. The work was done by contract, April 20, 1903, to June 21, 1904. From Nov. 20, 1903, to April 11, 1904, work was closed down on account of cold weather. The extreme height of the dam is 96 ft., and its length of the crest is 410 ft.; the thickness at the base is 56 ft., and on the top it is 10 ft. It contains 14,222 cu. yds. of granite rubble masonry laid in 1:4 Portland mortar, except for the face of stones where 1:3 mortar was used. The mortar constituted 35.2% of the dam; and 0.61 bbl. cement was used per cubic yard of masonry.

The mortar was mixed with a Smith mixer, in batches of ½ cu. yd., and the mixer output was 6 cu. yds. per hr. The mortar was dumped into buckets and carried on cars running on a trestle built along the up-stream face of the dam. Derricks on top of the dam hoisted the mortar buckets.

The granite was a gabbro, quarried about 100 ft. below the dam. It was devoid of cleavage and was blasted out in large masses from an open face 20 to 40 ft. high. The drilling was done by hand. For each cubic yard of rock there were used 0.35 lb. of dynamite and 1.05 lbs. of black powder The stones averaged 2 cu. yds., but pieces containing 5 cu. yds. were used.

Rocks breaking smaller than 3 cu. yds. were used as they were blasted out of the quarry, and larger masses were split up by plug and feather into roughly rectangular shapes. The best shaped stones were used for face stones, the ordinary rough rocks were used in the body of the dam, and the smaller pieces made the spalls. The rock was taken from the quarry by a guyed derrick with 40-ft.

boom, and loaded upon platform cars. The track was laid upon such a grade that the loaded cars ran alone and the empties were pushed back by hand. The trestle which carried the track was supported by the steps on the down-stream side of the dam. Upon the top of the dam were located two guyed derricks with 40-ft. booms similar to the quarry derrick. Each of the three derricks was operated by a 10-ton hoisting engine located in an engine house near the south end of the dam. The derricks on top of the dam took the rock from the cars on the lower side of the dam and set them in the masonry. They also took the mortar buckets from the cars on the up-stream side of the dam and dumped them where needed on top of the dam.

Spalls were brought upon the dam in skips, holding about a cubic yard each, and kept in the skips until used. The mortar was usually dumped in half-yard batches in a convenient depression of the masonry, and was distributed with long-handled, round-pointed shovels.

The up-stream face was laid with the joints in the true plane of the face. No objection was made to having the convexity of a stone project beyond this plane, but no stones with concave faces were permitted in the face of the dam. The upper 20 ft. of the down-stream face were laid in the same manner, but the rest of the down-stream face was laid in rough steps with half the step inside and half outside the theoretical plane of this face. The stone in both these faces were laid to break joint and were well bonded into the body of the dam. In the body of the dam but little attention was paid to the bond of the work, the irregular stones insuring this without effort, but every precaution was taken to insure the filling of voids. To this end the mortar was used very wet, even sloppy, and the chief rule observed was that there should first be placed a large excess of mortar of which the largest possible percentage was to be displaced by rock. In setting the large rock, a bed was prepared with spalls and mortar, and then a considerable excess of mortar was placed on the bed. The rock was then slowly lowered and settled on the bed by working it with bars. The excess mortar would ooze from under the rock which would then float upon an even layer of mortar, filling all the spaces under it. During this operation the inspector, either standing upon the rock or having his hand upon it, can tell if the rock is riding or

rocking, and, if necessary, has the rock raised and the bed readjusted. The large rock were set as close as possible to each other without being in contact, the intervening spaces being filled with mortar and spalls. In this work the masons were not permitted to sandwich the spalls between layers of mortar, but were required to first fill the space with wet mortar in which the spalls were submerged, displacing as much as possible of the mortar. While it was the intention to have the masonry brought up in horizontal benches extending the full length of the dam, the exigencies of the work prevented this and the middle portion of the dam was completed first, stepping off toward each end. The average rate of progress was 60 cu. yds. of masonry per day of ten hours. The best monthly rate was 2,370 cu. yds. during July, 1903, averaging 83 cu. yds. for a ten-hour day, or 41.5 yds. of masonry per ten-hour day for a single derrick, including the time lost in moving and resetting derricks. During this month the average daily force employed was as follows: In the quarry, 21.3 men, 1⅓ engine runners, and one derrick; in screening and hauling sand, 3.2 teams with drivers, and 3.2 men; in mixing and delivering mortar, 3 men; in laying masonry, 3.5 masons, 6.5 helpers, 2⅔ engine runners, and 2 derricks.

The following were the average wages paid per 10-hr. day: Quarrymen, $2.50; masons, $5.00; masons' helpers, $2.25 to $2.50; engine runners, $3.00; common labor, $2.25.

The actual cost of the masonry was as follows:

	Per cu. yd.
0.652 cu. yd. solid rock, $1.96	$1.28
0.348 cu. yd. mortar (not incl. cement), at $1.93	0.67
0.613 bbl. cement, at $3.58, delivered	2.19
Labor laying 1 cu. yd.	1.11
Total	$5.25

The solid rock was quarried and delivered for $1.96 per cu. yd. (solid), itemized as follows:

Quarrying and Delivering:	Per cu. yd. (solid).
Common labor	$1.06
Engine runners	0.14
Coal, $6 per ton	0.08

	Per cu. yd. (solid).
Blacksmithing	$0.13
Steel	0.04
Explosives	0.15
Interest and dep. on plant ($1,644)	0.18
General expenses	0.18
Total per cu. yd. (solid)	$1.96

This is equivalent to $1.28 per cu. yd. measured in the dam.

The cost of securing the sand and mixing the mortar was as follows per cu. yd. of mortar:

	Per cu. yd.
Labor digging and hauling (teams) sand	$1.10
Blacksmithing, sand pit	0.13
General expense, sand pit	0.19
Labor mixing and delivering	0.30
Fuel, $6 per ton	0.04
Interest and depreciation on plant ($620)	0.12
General expense	0.05
Total per cu. yd. mortar	$1.93

The cost of laying the masonry was as follows per cu. yd. of masonry:

	Per cu. yd.
Labor, masons and helpers	$0.50
Engine runners	0.18
Fuel, $6 per ton	0.10
Blacksmithing	0.02
Interest and depreciation on plant ($3,000)	0.22
General expense	0.09
Total	$1.11

The interest and depreciation on the plant was assumed to be 50% of the first cost of the plant. The fuel was estimated on the basis of 5 lbs. of coal per horse-power hour of actual working time for the nominal horse-power of the engines. As a matter of fact, a large amount of cord wood was used instead of coal.

Cost of a Rubble Dam.—This dam was built in 1898 by contract, under the direction of Mr. George W. Rafter, M. Am. Soc. C. E., across the Indian River, Hamilton County, N. Y., and is described in Engineering News, May 18, 1899. The main dam was 7 ft. wide on top, 47 ft. high, 33 ft. wide on bottom, and 400 ft. long. The face masonry was dressed to lay 1½-in. joints. The backing was large irregular rubble stones laid in beds of 1 : 3¼ mortar, and the vertical joints filled with 1 : 3¼ : 7½ concrete. No attempt was made to keep separate accounts of the face masonry and the backing, but it was estimated that 27% of the dam was mortar. The stone was a pink synetic granite, quarried 500 ft. from one end of the dam. There was no difficulty in quarrying regular blocks for the face. The sand was loaded upon a scow holding 30 cu. yds. and hauled 2 miles down the river. A foreman and 6 men, by using a windlass, rope and sail, handled the scow. They loaded and delivered 720 cu. yds. of sand and 180 cords of wood per month, at a cost of about $310. Wages of common laborers were $1 a day and board, and it is probable that the board cost $0.50 per man per day.

The plant to build the dam cost $10,340. The actual cost of the dam to the contractor was:

Labor clearing 35 miles of margins, 1,160 acres....	$13,000
Hauling cement and supplies 22 miles	6,836
Freight, cement and supplies	960
Barn account (teams owned by contractor)	725
Stone, cement and other materials	18,830
Labor (not including clearing)	31,218
General expense	9,601
Interest	1,150
Insurance	1,235
Depreciation of plant, est. 33%	3,450
Total	$87,005

The "general expense" includes coffer-damming and pumping, erecting and wrecking the plant, etc. The time occupied in doing the work was 7 months.

In July and August, when the work was well under way, the cost of the masonry was very low, and averaged as follows:

	Per cu. yd.
Quarrying face stone (not incl. backing)	$0.35
Labor laying masonry	0.53
" pointing masonry	0.15
Mixing mortar and concrete, and crushing	0.20
Cement	2.00
Sand	0.15
General expense and superintendence	0.27
Total	$3.65

In addition to this there was the cost of quarrying the stone for the backing; but this stone was paid for as excavation, so it is not included above. During July and August this excavation cost 46 cts. per cu. yd.

It will be noted that the accounts were not well kept, for no statement is given of the proportion of backing to face stone. The quarrying of the face stone doubtless cost several dollars per cubic yard of the face stone, although it amounted to only $0.35 per cu. yd. when distributed over all the masonry. Nor is it stated what the dressing cost. From measurements on a drawing of the cross-section of the main dam, I estimate that it runs 29 cu. yds. of masonry per lin. ft., of which about 30% is face stone, if we allow a depth of 2½ ft. of face stone extending into the dam; but in the lower third of the dam, where there is great breadth, the face stone would not be more than 20% of the total masonry, and at the bottom only 15%. Hence if the work in July and August was in the lower part of the dam, as it doubtless was, we must multiply the $0.35, above given, by at least 5 to secure an approximate estimate of the cost of quarrying a cubic yard of the face stone. Indeed, it is likely that the cost of face stone was more than 5 times $0.35 per cu. yd.

I have gone into these details for the purpose of showing how little value there often is in published cost records, be-

cause of the failure of engineers to keep their cost records properly. The wages of quarrymen and masons are not given.

Data on Laying Masonry With a Cableway.—In Trans. Am. Soc. C. E., Vol. 31, 1894, Mr. Spencer Miller gives data on the use of cableways for laying masonry. The Basin Creek Dam for the water-works of Butte, Mont., is 120 ft. high and 300 ft. long, designed by Mr. Chester B. Davis. A cableway, 892 ft. between towers, spanned the dam and the quarry. No derricks were used on the dam, for, by using a snubbing post and a horse, the stones could be swung where desired. In 16 days a gang of 86 men quarried and laid 1,430 cu. yds. of masonry. This gang included 6 masons, quarrymen, firemen, and all laborers about the dam and camp. These six masons averaged 15 cu. yds. of masonry each per day.

At Rochesteer, N. Y., two cableways, side by side and 60 ft. apart, were used to erect a stone arch bridge 630 ft. long and towers 50 ft. high. A 30 HP., 8¼ × 10-in., engine was used for each cableway. Stones were laid between the cableways by hitching the hoisting lines of both cableways to the same stone. To lay the masonry piers a frame was used which straddled the piers and on top of which a traveler was used to place the stone as fast as it was delivered by the cableway. After a pier was completed the framework and traveler were lifted by the cableways to the site of the next pier, in less than 10 minutes. The centers for the arches were lifted into place by the cableways. This highway bridge contained 2,200 cu. yds. of masonry in piers and arches, 2,278 cu. yds. arch sheeting, 2,660 cu. yds. concrete spandrel backing, and 310,000 lbs. of iron work; 350 M of lumber were used in the centers.

Cost of Masonry and Timber Crib Dam.—Mr. Maurice S. Parker, M. Am. Soc. C. E., gives data on the Black Eagle Falls Dam, Missouri River, Great Falls, Mont. The work was done by day labor (Apr. 15, 1890, to Jan. 6, 1891) under Mr. Parker's supervision, wages being as follows: Common labor, $2; stone masons, $4; carpenters, $3.50; quarrymen, $2.25; stone cutters, $4.50; quarry foremen, $3.50; mason

foremen, $5; stone cutter foremen, $5; carpenter foremen, $5.

The stone was a red sandstone weighing 160 to 170 lbs. (some specimens 178 lbs.) per cu. ft., and was quarried from the bed of the river, the average haul being 500 ft. on push cars. The stone occurs in vertical strata 1 to 4 ft. thick, the bedding planes making an angle of 45° with the current. Timber was delivered near the gate chambers. Cement used was Milwaukee and Buffalo mixed 1:2. Portland cement was used in freezing weather and gave perfect satisfaction, being now as hard as stone. The following table gives the cost of the labor in construction, including all handling of materials after unloading from cars:

	Cost of labor.
4,600 cu. yds. first class rubble, at $6.56..........	$30.438
1,500 cu. yds. cut stone masonry, at $16.40.......	24,600
5,000 cu. yds. dry stone filling in cribs, at $2.10..	10,500
10,000 cu. yds. excav., half rock, half earth, at $1.07	10,700
1,200 M timber in cribs, at $10.85	13,020
100 M timber in gates and chambers, at $33.72	3,372
Engineering expenses, 12 mos....................	5,900
Total cost of labor	$98,530

The expense of false work of all kinds, such as cofferdams, tramways, etc., amounted to 5% of the total cost and is divided proportionately between the classes of work above given. The cost of labor on timber in gates and chambers includes the cost of placing all irons and gearing. The total cost of the dam was $175,000, including materials, labor and salaries. About 20% of the rubble was broken range faced. The cut-stone masonry was laid with close beds and joints.

The minimum flow of the river is 4,000 cu. ft. per sec. The average depth of water was 2 ft. when work was begun, but it was very swift as the rapids at the site of the dam had a fall of 2 ft. in a 100 ft. During June floods the depth was 6 ft. The crib dam is 745 ft. long, and the canal and gates occupy an additional width of 95 ft. The average height of the dam is 14 ft., resting on a ledge of sandstone.

The longitudinal timbers of the crib are spaced 8 ft. c. to c. The bottom timbers were cut to fit the rock, bedded in cement mortar and drift bolted to plugs of wood driven into holes drilled in the ledge rock.

The work was begun on the north side of the river, a sheer dam being first built to divert the stream from the dam site. This sheer dam consisted of wooden horses placed 8 ft. apart, with stringers of 4-in. plank. A facing of 2-in. tongue and grooved planks was placed on the up-stream legs of the horses, and a row of sand-filled bags placed at the toe of the planks. There was a little leakage, and the leakage water was diverted by a second row of sand bags parallel with the first row, and a short distance down stream. This sheer dam withstood a flood 6 ft. deep.

On the south side of the river, which was deeper and swifter, it was necessary to sink small triangular stone-filled cribs to support the wooden horses for the sheer dam. These cribs were of 4-in. plank with 6-in. posts, each holding 1 cu. yd. of stone, and were placed 8 ft. apart, each crib supporting a horse. At times the depth of water against this sheer dam was 15 ft., but the leakage was easily cleared with hand pumps.

To close the long gap between the two ends of the dam, wooden horses were placed 8 ft. apart with a foot walk of 4-in. plank on top, and heavy timbers to hold the horses down. From this temporary bridge a second tier of horse bents was placed (8 ft. c. to c.) on the up-stream side, connected with 4-in. stringers and sheeted with 4-in. plank. The dam was intended to break the force of the current, which it did admirably. The leakage was taken care of in sections by small sheer dams built of matched plank, and by the use of sand bags. Every 48 ft., an opening of 14 ft. was left in the crib dam which was used as a temporary sluiceway when the coffer dam was removed. These gaps were subsequently closed with planks, and the cribwork with its stone filling built in.

Cost of Laying Masonry, Dunning's Dam.—In Trans. Am. Soc. C. E., Vol. 32, p. 389, Mr. E. Sherman Gould describes The Dunning's Dam near Scranton, Pa. The dam is

masonry on a concrete foundation, built by contract. The stone for the masonry was a conglomerate laid in swimming beds of mortar. On one occasion one foreman, 8 masons and about 9 helpers laid nearly 500 cu. yds. of rubble in 76 hrs., using a double drum engine and derrick. This is equivalent to 8.2 cu. yds. per 10-hr. day per mason. On another occasion, another foreman, 7 masons and 8 or 9 helpers laid 375 cu. yds. in 7 days, or 7.6 cu. yds. per mason per day. This was very rapid work in both cases.

Cost of Quarrying and Laying a Limestone Wall.—Mr. James W. Beardsley is authority for the following data on the cost of quarrying and laying limestone for retaining walls on the Chicago Canal. The contractors selected parts of the canal where the limestone occurred in strata that were uniform, so that the beds of the stone quarried required no dressing. The stone was laid in courses averaging about 15 ins. thick, the better stone being selected for the face of the wall. Guy derricks having a capacity of 6 to 10 tons, boom 40 to 60 ft. long, operated by a hoisting engine, were used for loading the stone. Black powder was used to shake up the ledges and the stone was then barred and wedged out. The cost per cu. yd. is the average of 93,500 cu. yds., measured in retaining walls. The mortar was only 13¼% of the wall, indicating an unusually even bedded stone that squared up well. The cost does not include general superintendence, installation of plant, plant rental, powder, material for repairs, and cost arising from delays.

Mr. Beardsley has evidently divided the number of working days credited to each class of men by the total number of days worked on the job, which results in giving fractions of days labor in the following typical force.

	Per cu. yd. masonry.
Quarry force:	
1 foreman, at $3.50	$0.078
2.11 derrickmen, at $1.50	0.075
8.42 quarrymen, at $1.65	0.312
1.10 enginemen, at $2.25	0.052
2.28 laborers, at $1.50	0.080
0.33 waterboy, at $1.00	0.007

	Per cu. yd. masonry.
0.27 blacksmith, at $2.50	$0.013
0.18 blacksmith's help, at $1.75	0.007
0.36 drill runner, at $2.00	0.023
0.07 drill helper, at $1.50	0.002
0.04 watchman, at $1.50	0.001
0.29 team, at $3.50	0.028
1.12 derricks, at $1.25	0.040
0.36 drill, at $1.25	0.015
Total quarry force	$0.733
Wall force:	
1 foreman, at $4.25	$0.113
4.20 masons, at $3.50	0.354
1.46 masons' helpers, at $1.50	0.058
1.81 mortar mixers, at $1.50	0.073
0.66 mortar laborer, at $1.50	0.027
1.82 hod carriers, at $1.50	0.073
1.77 derrickmen, at $1.50	0.071
1 engineman, at $2.25	0.054
1.62 laborers, at $1.50	0.065
0.45 waterboy, at $1.00	0.009
0.86 team, at $3.50	0.078
0.20 carpenters, etc., at $2.50	0.010
1.59 derricks, at $1.50	0.042
Total wall force	$1.027

This wall force of 16 men laid 37 cu. yds. per 10-hr. day, each mason averaging 8.8 cu. yds. The rates for derricks, etc., apply to the cost of fuel, at $2 a ton. The wall derricks were stiff-legs, having booms 40 ft. long, and were moved on a track parallel with the wall.

Work was done between Sept., 1894, and Oct., 1896, with a plant having a total value of $30,200. The total cost of the masonry was as follows:

Quarry force	$0.73
Wall force	1.03
Sand, at $1.35 per cu. yd.	0.13
Cement, at 60 cts. per bbl.	0.24
Total	$2.13

If the full cost of the plant is charged to the work, another 32 cts. per cu. yd. must be added for plant.

The mortar was mixed 1 : 1, and Louisville (natural) cement was used, each bag being called 2 cu. ft.

The wall averaged 24 ft. high, and was 4 ft. wide for the upper 8 ft., then it widened to 12 ft. at the base. It was laid in courses 12 to 18 ins. thick.

Cost of Laying Bridge Pier Masonry.—Mr. Gustave Kaufman gives the following data on the abutments and piers of a highway bridge across the Ohio River at Cincinnati. The total length of the bridge is 2,966 ft., with a 24-ft. roadway and two 7-ft. sidewalks. There are two abutments, nine masonry piers, of which four piers are founded on limestone, and five on piles. There are 28 pedestals for the steel viaduct approaches. The center span of the bridge has a clear height of 102 ft. above low water. Work on the substructure was begun May 1, 1890, and floods caused many delays, so that the bridge was not opened till Aug., 1891.

Louisville cement was used throughout, except Portland cement for pointing. Piers Nos. 1, 2, 3 and 9 are Ohio River freestone, with a backing of freestone. Where pile foundations were used, the heads of piles were imbedded

DIMENSIONS OHIO RIVER PIERS.

Pier No.	Size Under Coping.	Height Over All.	Size at Base of Shaft.	Cubic Yards Masonry.	Remarks.
	Feet.	Feet.	Feet.		
1	5 × 30	26.2	6.4 × 31.4	146.2	Square shaft.
2	5 × 30	39.4	7.6 × 32.6	271.7	"
3	6 × 30	47.0	9.1 × 33.1	393.9	Circular shaft.
4	9 × 34	74.0	13.8 × 49.5	1,432.9	"
5	10 × 34	112.8	17.3 × 53.7	2,357.6	"
6	10 × 34	104.1	17.8 × 54.2	2,475.6	"
7	9 × 34	93.4	16.0 × 51.8	1,974.1	"
8	7 × 32	87.1	13.4 × 46.8	1,393.3	"
9	7 × 32	37.3	9.6 × 34.6	330.1	Square shaft.

NOTE.—Pier No. 3, height includes caisson. The coping of all piers was Bedford oolitic limestone 18 ins. thick, except for piers 5 and 6 which had a 24-in. coping. There were 2,173 cu. yds. of masonry in the ramps on both sides of the river.

in 3 to 4½ ft. of concrete foundation. Piers 4 to 8, inclusive, are of Berea sandstone with a backing, or hearting, of concrete, up to the belt course, above which the masonry is Ohio River freestone entirely. The dimensions of the piers are shown in the table on page 225.

The masonry was laid with the help of derrick scows, and the cost of laying the 280 cu. yds. above the starling course was $1.25 per cu. yd., including the cost of sand and cement. The cost of laying the sub-coping and coping was $1.45 per cu. yd., including sand and cement. The cost of laying masonry and concrete, courses 5 to 21, was $1.30 per cu. yd., including sand and cement. These costs do not include cofferdams. Wages were as follows, per 10-hr. day: Common labor, $1.50; masons, $3.25; stone cutters, $3.50; engineman, $2.00; foreman, $4.00.

The face stones were laid alternate headers and stretchers, stones being not less than 3½ ft. long, dressed to ⅜-in. bed joints and ⅜-in. vertical joints for at least 12 ins. back of the face. The width of each stone was 1¼ times the depth of the course.

The cost of laying Pier 5 was $0.73 per cu. yd., courses 1 to 37; and $1.11 per cu. yd., courses 38 to 54; and $1.10 per cu. yd., courses 55 and 56; the cost of sand and cement is included in all cases.

Cost of the Sodom Dam.—In Trans. Am. Soc. C. E., Vol. 28, 1893, p. 185, Mr. Walter McCulloch gives the following data on the Sodom Dam, on the east branch of the Croton River, N. Y. The dam is 500 ft. long at the coping, 240 ft. long at top of foundation, 53 ft. thick at foundation, 12 ft. thick under coping, and 78 ft. high above ground line. Work was begun Feb. 22, 1888, and completed Oct. 29, 1892. The contractor paid laborers $1.25 a day, and masons, $3.50. There were 35,887 cu. yds. of masonry of all classes. Of this 23,600 cu. yds. were rubble laid in 1 : 2 Portland mortar, 6,300 cu. yds. rubble in 1 : 3 mortar, 780 cu. yds. of granite dimension stone masonry, 4,300 cu. yds. limestone face masonry, and 530 cu. yds. of brick masonry. The face masonry and brickwork were laid in

PIER No. 4—OHIO RIVER.

No. of course.	Size of course out to out, ft.	Thickness of stone, ins.	Cu. yds. face masonry.	Cu. yds. backing.	Cu. yds. mortar in all joints.	Face work, per cent. of whole.	Bbls. cement per cu. yd. face.	Bbls. cement per cu. yd. backing.	Remarks.
1	23.2 × 59.2	19	30.9	46.1	1.45	40%	.26	1.70	Footings.
2	21.4 × 57.3	19	29.4	39.7	1.05	43%	.37	1.64	"
3	19.4 × 55.2	32	53.3	47.4	1.30	53%	.32	1.52	"
4	16.4 × 52.2	28	32.4	39.0	.93	45%	.37	1.79	"
5	13.7 × 49.4	26	28.4	22.7	.88	58%	.35	1.68	Masonry (with concrete backing), having semi-circular ends.
6 to 11	Averages =	26	27.8	20.6	.86	58%	.26	1.80	
12	12.4 × 48.1	25	26.4	17.7	.84	60%	.26	1.81	
13 to 20	Averages =	24½	24.9	15.0	.80	63%	.33	1.70	
21	10.7 × 46.4	24	24.1	11.0	.80	69%	.29	1.63	
22	11.8 × 47.5	22	23.1	12.7	6.20	65%	.42	Included with face work.	Starling course.
23 to 24	Averages =	17	15.1	9.5	4.80	62%	.50		Hood courses.
25	10.5 × 35.5	18	10.0	12.1	8.40	45%	.53		Masonry with rubble backing, courses 22 to 38.
26 to 36	Averages =	16½	11.0	6.5	3.14	63%	.59		
37	9.0 × 34.0	15	8.9	5.8	2.95	60%	.47		
38	10.0 × 35.0	18	13.8	6.2	2.99	69%	.50		Sub-coping.
39	11.0 × 36.0	18	21.8	....	.72	100%	.50		Coping.

NOTE.—Cement per cu. yd. face work, courses 1 to 21 = 0.30 bbls.
Cement per cu. yd. concrete, courses 1 to 21 = 1.71 bbls.
Cement per cu. yd. masonry, courses 22 to 39 = 0.56 bbls.

All face stones had a width 1¼ times their thickness, and below the starting course were laid with Flemish bond, alternate headers and stretchers. Mortar was 1 to 2; concrete was 1:2:4, broken stone; Louisville cement throughout.

PIER No. 5—OHIO RIVER.

No. of course.	Size of course, out to out, ft.	Thickness of stone, ins.	Cu. yds. face masonry.	Cu. yds. backing.	Cu. yds. mortar in bed joints.	Face work, percentage of whole.	Remarks.
1	19.5 × 55.5	27	33.3	52.6	1.62	31%	Footing
2 to 3	19.0 × 55.0	26	30.4	49.5	1.54	38%	"
4 to 9	Averages =	25	28.9	35.3	1.28	45%	Semi-circular ends.
10	16.2 × 52.5	24	26.0	32.9	1.22	44%	"
11 to 21	Averages =	24½	26.8	28.6	1.13	48%	"
22	14.1 × 50.5	24	25.2	24.4	1.04	51%	"
23 to 32	Averages =	21¼	21.7	19.3	.96	58%	"
33	12.4 × 48.7	21¾	22.3	16.4	.88	59%	"
34	13.3 × 49.6	21¾	23.3	17.5	.86	57%	Starling course
35 to 37	Averages =	17	16.5	10.2	.78	62%	Hood courses
38 to 44	Averages =	16	13.5	7.2	.63	65%	Rectangular ends
45	11.1 × 35.1	16	12.7	6.4	.60	66%	"
46 to 53	Averages =	16	12.6	5.4	.57	70%	"
54	10.1 × 34.0	14	10.4	4.3	.53	70%	"
55	11.0 × 35.0	24	20.6	7.9	.53	72%	Sup-coping
56	12.0 × 36.0	24	32.0	....	.59	100%	Coping

NOTE.—Between courses 1 to 33 the Louisville cement used was .33 bbl. per cu. yd.; courses 34 to 54 used .30 bbl. per cu. yd.; courses 55 and 56 used .35 bbl. per cu. yd.

Percentage of face work, courses 1 to 33 was 46.4%.

Percentage of face work, courses 34 to 54 was 65.8%.

Mortar was 1 to 2 throughout. There was one header to every three stretchers, no face stone being less than 3½ ft. long, and dressed to ⅝ in. joints. No spaces wider than 6 ins. allowed between backing stones.

1 : 2 Portland mortar. The rubble was quarried 1¼ miles from the dam and hauled on double team trucks carrying 1 to 1½ cu. yds. per load, making 6 to 8 trips a day. The rock was a hard, close grained gneiss of irregular cleavage. The face stones (4,300 cu. yds.) were quarried at a limestone quarry 7 miles away and delivered on cars of the N. Y. & N. E. R. R. These stones were cut for 30-in. courses, stretchers being 3½ ft. long, and headers 4 ft. long. Dimension stones (780 cu. yds.) were granite from Wilmington, Del. Cement cost from $2.31 to $2.51 per bbl. The cost of the rubble stone delivered on the work from the quarry was $1.97 per cu. yd., including 5 cts. quarry royalty. Rubble stone and spalls from the excavation waste banks cost $0.67 per cu. yd. The average cost of rubble stone was $1.26. The actual cost of rubble masonry in 1 : 2 mortar was $4.45 per cu. yd. The actual cost of limestone for face work was $9.75 per cu. yd., including 15 cts. quarry royalty, but not including laying and mortar. The cost of dimension granite on the work, including dressing, was $30.08 per cu. yd. The cost of the coffer-damming and other work is not given.

A cableway spanned the dam, 2-in. cable, 7 lbs. per ft., 667-ft. span, sag 25 ft. under 10-ton load. The cableway plant cost $3,800. After four months' use the cable, under a load of only 6 tons, broke 50 ft. from one tower, at a place where stone and cement skips were taken up. A new cable was installed, the towers raised 10 ft. so as to give it more sag, and it served till the end of the work. The cableway anchors were oak deadmen, 2 ft. diameter by 10 ft. long, in trenches in rock 6 ft. deep. The masonry was laid with fixed derricks and with a traveling derrick on a 30-ft. trestle running upon a track of 36-ft. gage. The best month's work was 3,000 cu. yds. laid with 12 masons and three derricks; the average progress was 1,700 cu. yds. per month. The Giant Portland cement came in duck bags of 100 lbs. each (93 lbs. net), four to the barrel. The Union natural cement came in 100-lb. bags (96 lbs. net), three to the barrel. The sand and cement were mixed dry (3 turns with shovels) and delivered in boxes on the work where it was wet as needed. Rubble

stones varied from 1 cu. ft. to 1 cu. yd. in size, and in placing them the beds of mortar were made very full and the stone thoroughly shaken till firm. Mortar was filled into the joints and then all the spalls that it would take were forced in. Care was taken not to build the rubble up in courses. In freezing weather, above 20°, hot brine (5 lbs. salt to 1 bbl. of water) and heated sand were used for the mortar. Salt and sand were sprinkled over the fresh mortar at night. In the spring the mortar laid in freezing weather could be scaled off 1-16 to 1-8 in. deep, but under this it was hard. In laying the foundation it was found that springs of water would wash the cement out of the concrete, so it proved better to lay beds of rubble made of small stones. The water could be led around the rubble and nursed from place to place till finally a small well, 2 ft. in diameter and 1 to 2 ft. deep, would be formed where the water boiled up. When the mortar about each little well had set, the water was bailed out, the well quickly filled with dry mortar, a bed of stiff wet mortar laid on top and covered with a large rubble stone. When the water was turned in behind this dam there were no leaks. This was in a large measure due to the use of rich mortar and careful work. No cracks developed.

Cost of Dams and Locks, Black Warrior River.—Mr. R. C. McCalla gives the following data relative to the cost of building masonry locks and dams on the Black Warrior River, Alabama. The work was done by hired labor for the Government, in 1888 to 1895. The stone is a sandstone quarried near the locks along the banks of the river and in the river bed. The stone for Lock and Dam No. 3 was quarried in a reef just above falls 7 ft. high. The quarry covered two acres, and was operated to a depth of 12 to 18 ft. during low water, requiring only two 3-in. Pulsometer pumps to keep it drained.

The face stone of locks Nos. 1, 2 and 3 were set in 1 : 3 Portland mortar (cement measured loose); the backing was partly set in mortar and partly in 1 : 3 : 5 concrete. Stiff-leg derricks were used to set the stones.

In October, 1891, 200 cu. yds. of backing and 600 cu. yds.

LOCKS ON BLACK WARRIOR RIVER.

	Unit	Lock No. 1.		Lock No. 2.		Lock No. 3.	
		Quantity	Rate	Quantity	Rate	Quantity	Rate
Stone quarried	cu. yds.	10,087	$3.41	11,282	$1.46	11,415	$1.66
Stone cutting	"	3,530	10.66	3,595	7.16	3,997	6.02
Laying masonry*	"	10,087	2.53	11,282	1.89	11,415	1.81
Earth excavation	"	10,809	0.28	6,876	0.24	3,529	0.26
Rock excavation	"	3,778	1.33	941	1.06	2,500	1.00
Earth filling	"	4,500	0.25	6,552	0.21	7,496	0.29
Rock filling	"	2,500	0.50	....	....	....	....
Paving, 12 ins. thick	sq. yds.	6,774 }	....	8,367 }	0.22	7,036	0.14
Turfing	"	3,132 }	....	1,021 }		....	....
Gates and valves	....	....	12,010.00	....	9,698.00	....	9,919.00
Coffer-dam and pumping	....	....	8,556.00	....	2,402.00	....	....
Handling and hauling stone	....	....	20,273.00	....	10,003.00	....	8,510.00
Boats and buildings	....	....	4,518.00	....	3,442.00	....	3,445.00
Track and roads	....	....	10,882.00	....	9,867.00	....	2,023.00
Tools and plant	....	....	28,535.00	....	22,513.00	....	17,852.00
Incidentals	....	....	6,771.00	....	5,841.00	....	5,713.00
Engineering and Supt.	....	....	19,405.00	....	13,841.00	....	13,892.00
Total	....	....	$221,079	....	$146,881	....	$131,561
Cost per cu. yd. masonry†	....	....	....	....	....	....	$9.93

* Including cost of cement.

† This does not include earth and rock excavation, earth and rock filling, paving and turfing, gates and valves.

of dimension stone were quarried for Lock No. 2, Black Warrior River, Tuskaloosa, Ala. The stone was a fine quality of blue sandstone quarried from the bed of the river at the falls, after diverting the water. The cost of quarrying these 800 cu. yds. was $1,598, or about $1 per cu. yd. for the backing and $2.33 per cu. yd. for the dimension stone. In this month 434 cu. yds. of dimension stone were cut by stone cutters at a cost of $6.83 per cu. yd. The masonry wall is 390½ ft. long, 8 to 14 ft. wide, and 34 ft. high, built in courses of ashlar 18 to 24 ins. thick, and about 50 per cent. cut stone. In October two gangs of masons, using two derricks, laid 1,563 cu. yds. of first-class masonry at a total cost of 92½ cts. per cu. yd., including the cost of screening sand, mixing mortar, operating steam hoists, unloading material at the wall and converting them into masonry. The itemized cost of the mason work was:

Foreman, 1 mo.	$90.00
Masons, 202 days of 8 hrs., at $2.80	565.60
Laborers, 35⅛ days of 8 hrs., at $1.20	42.15
Laborers, 270½ days of 8 hrs., at $1.00	270.50
Laborers, 369⅝ days of 8 hrs., at $0.80	295.70
Laborers, 146¾ days of 8 hrs., at $0.60	88.05
Boys, 83¼ days of 8 hrs., at $0.40	33.30
Wages paid in board	42.00
Fuel for hoists	18.49
Total, at 92½ cts. per cu. yd.	$1,445.79

It will be noted that the wages of laborers were very low. Doubtless the men were negroes.

On the south wall of Lock No. 2, Black Warrior River, during Aug., 1892, two gangs of masons, three masons to the gang, with helpers, laid and pointed 2,370 cu. yds., about 40% of which was dry rubble wall, the rest being fist-class masonry in Portland cement mortar. This is 16 cu. yds. per mason per 8-hr. day. The following includes the cost of screening sand, mixing mortar, unloading materials at the wall, operating steam hoists, fuel for same, laying and pointing the masonry:

Foreman, 1 mo.	$100.00
Masons, 147½ days, at $3.50	516.25
Laborers, 27½ days, at $1.50	41.25
Laborers, 108 days, at $1 25	135.00
Laborers, 510½ days, at $1.00	510.50
Laborers, 216 days, at $0.80	172.80
Laborers, 186½ days, at $0.75	139.88
Laborers, 103 days, at $0.55	56.65
Boys, 87¾ days, at $0.50	43.88
Wages paid in board	100.00
Fuel	22.75
Total, at 77.6 cts. per cu. yd.	$1,838.96

Cost of Rock-fill Dams.—The three dams on the Black Warrior River, built by hired labor, were of the rock-fill type without mortar or core-walls. The down stream face is composed of large roughly dressed stones, laid in steps and dowelled together. A timber crib is built into the upper face of the dam and sheathed with 6 × 12-in. plank. The dams were built during low water, without cofferdamming. Floating and stationary derricks were used. Sandstone for dams Nos. 1 and 2 was delivered by barge, and for No. 3 by rail, a track being laid on stone-filled cribs along the toe of the dam. The cost of this work is given in the table on page 234.

		Crib No. 1.		Crib No. 2.		Crib No. 3.	
Lumber and iron	Ft.B.M.	34,453	$13.65	33,109	$12.68	33,109	$14.16
Carpenter work	Ft.B.M.	34,453	6.94	33,109	6.83	33,109	12.62
Filling rock	Cu. Yds.	1,640	0.35	1,105	0.24	1,090	0.46
Total		......	$1,277	......	$909	......	$1,390

NOTE:—Crib No. 1 is 29 ft. 10 ins. high, 11 ft. 8 ins. wide, and 90 ft. long; Cribs Nos. 2 and 3 are 28 ft. 8 ins. high, 11 ft. 6 ins. wide, and 90 ft. long. The cribs are of 6 x 8 in. yellow pine with cross-pieces at intervals of 5 ft., drift-bolted together, and filled with one-man stone.

Cost of Limestone and Sandstone Slope-Walls.—The following is an abstract of one of my articles appearing in Engineering News, June 11, 1903:

A slope-wall is practically a stone block pavement laid upon a sloping face of earth to protect it from erosion. The "wash" of passing boats in canals makes necessary some such protection of the earth in certain places. The beating of waves upon the sides of a reservoir or small lake acts in a similar manner, and a slope-wall is usually provided to resist the erosion. The concave side of a

COST OF ROCK-FILL DAMS, BLACK WARRIOR RIVER.

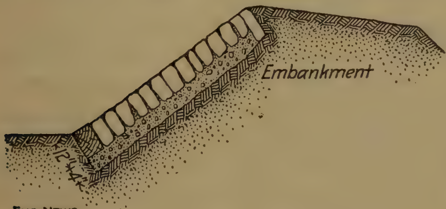
	Unit.	Dam No. 1.		Dam No. 2.		Dam No. 3.	
Lumber and iron	Ft. B. M.	36,238	$27.89	53,556	$15.89	93,759	$13.59
Carpenter work	"	36,238	9.28	53,556	7.13	93,759	7.36
Stone quarried	cu. yds.	1,467	8.41	3,646	0.92	6,130	0.68
Stone dressed roughly	"	360	2.94	373	1.69	893	1.17
Laying masonry	"	1,467	0.85	3,646	0.51	6,130	0.31
Earth excavation	"	329	0.18	360	0.13	....	....
Filling above dam	"	502	0.85	607	0.66	1,444	0.60
Cement	....	....	....	....	135.00	....	135.00
Handling and hauling	....	....	465.00	....	587.00	....	1,168.00
Track and roads	....	....	100.00	....	106.00	....	635.00
Tools and plant	....	....	555.00	....	964.00	....	2,669.00
Incidentals	....	....	144.00	....	497.00	....	145.00
Engineering and Supt	....	....	477.00	....	1,082.00	....	1,278.00
Total	....	....	$10,879	....	$10,902	....	$16,337

NOTE.—Dam No. 1 is 10 ft. high, 21 ft. wide at base, and 339 ft. long; No. 2 is 13 ft. high, 24 ft. wide at base, and 410 ft. long; No. 3 is 15 ft. high, 26 ft. wide at base and 650 ft. long.

river bank is occasionally protected by slope-walling, with perhaps a line of piling at the toe of the wall.

A dry slope-wall, it will be seen, is an engineering structure often used, although very little exists in print as to its design or cost. Since the forces acting upon a slope-wall are not readily measurable,, the design is an art, and not a science. Recorded experience of others, personal experience of the designer and common sense should govern the design.

The oldest slope-walls on the Erie Canal were made of cobblestones rammed solidly into the bank, and placed so that the stones touched one another. Cobbles for this purpose were gathered from fields or creek beds, and ranged in diameter from 4 ins. to 12 ins., the average being about



Eng. News.

Fig. 8. Cross-section of Slope Wall.

Fig. 9. Face of a Good Second-class Slope Wall.

6 or 8 ins. These cobble slope-walls while not as handsome as those made of dressed quarry stone were in fact more durable, for the shales and limestone ledges along the route of the Erie Canal furnish stone more or less subject to weathering. Cobbles, or "hardheads," on the contrary, are often granitic and always tough.

Slope-walls made of quarry stone are built as shown in Figs. 8 and 9. The stones are split with wedges or plug and feathered, then roughly dressed with a hammer, and placed in the wall on edge, just as brick or stone block are placed in a street pavement. The longest dimension of the stone is laid parallel with the axis of the canal or river. In some of the earlier walls, huge slabs of stone were laid flatwise just as sidewalk flagging is laid, but such stones are apt to settle unevenly and tilt up so that a passing boat or moving ice will displace them entirely. Moreover

it is practically impossible to bed very large stone properly, since ramming has no effect. Experience, therefore, has shown the necessity of splitting up slabs into blocks readily laid and bedded by hand; and it costs no more in the end to build walls in this way, for the cost of handling with a derrick and cost of frequent moving of derrick more than offset the cost of splitting the stone. It is customary on the Erie Canal always to provide a lining of gravel (Fig. 8) back of the wall. This lining serves a twofold purpose: It makes it easy for the workman to bed jagged stone properly, and it further adds to the protection of the subsoil from wash. Waves beating through the joints in the slope-wall strike this gravel which is not easily displaced, and do not reach the subsoil with sufficient force to displace it. It is the writer's opinion that this gravel lining is one of the most important and necessary features of a well-made slope-wall. Crushed stone, of course, would serve equally well or better, but usually the cost is more than for gravel. There are places where broken stone costs less than gravel and in such places it should be used.

On rivers or reservoirs, subject to wide fluctuation in water level, the gravel or stone lining for the paving is even more necessary; for there the surface rain water, flowing down over the face of the slope-wall, will cut rivulets beneath it unless proper lining is provided. Embankments are usually so designed as to prevent much rain water from flowing over the slope-wall face, as shown in Fig. 8, where the towpath is seen to have a slope away from the canal. In diking a river the same form of top slope is usually provided where a slope-wall is to be laid; but in protecting a natural river bank it is often impossible entirely to prevent rain water from flowing over the face of the slope-wall. Ditches should be dug to divert the rain water, which is then carried in a pipe culvert through to the river. Ditches, however, are apt to fill up with washed-in earth, so that in any event a substantial lining of gravel should be placed back of the slope-wall, in order to guard against erosion by rain water. A thickness of gravel lining of from 4 to 8 ins. will suffice, 4 ins. ordinarily being enough.

Passing to the thickness of the stone slope-wall itself, we find a range of from 6 ins. to 24 ins. with 12 to 16 ins. most commonly used. The Chemung River, near Elmira, N. Y., is a stream about 600 ft. wide and 20 ft. deep in times of high water. At one place on this river a slope-wall 24 ins. thick was built by the State, and a few miles away another had been built 12 ins. thick, both of a shaley limestone. Both walls have served for years, except in places where the piling at the toe has been undermined. The 24-in. wall was evidently an extravagant design; and not justified by the conditions, particularly as the lighter wall had been in service some years before the construction of the 24-in. wall was begun. Because a river is occasionally a raging torrent it does not follow that the floating debris or ice will displace the small stones of a well-laid slope-wall. As a matter of fact, each stone is held by the weight of stones above, even when laid on a 1½ to 1 slope, and a stone is pried out of a slope-wall with great difficulty. The writer believes that ordinary brick laid dry as a slope-wall pavement will protect a river embankment perfectly, provided the subsoil does not become undermined. In slope-wall masonry, on river embankments subject to blows of ice and logs, a thickness of 8 to 10 ins. seems an advisable minimum, for some erosion and settlement of the subsoil or lining must be provided for. On reservoirs or canals a less thickness may be used where blows from boats are not frequent. But as above stated 12 ins. is very often specified, and as will be seen later, it is not an extravagant depth. Having fixed upon the depth of stone to be used in the wall, the thickness (or rise) and length remain to be determined. A minimum thickness of 4 ins. is usually specified. As a matter of fact, except for appearance sake, thickness is not an important factor. An engineer who is fond of seeing coursed masonry will often require that the slope-wall be laid in courses of a specified minimum and maximum thickness. It costs money to dress the stone to lay in such courses, but for appearance sake, near a highway, such expense may be justified. Ordinarily it is not justifiable. Slope-walls are built for protection, not for beauty.

If any definite minimum thickness of courses is specified, it should be governed by the stratified thickness of stone in the nearest quarry. If the quarry is thick-bedded limestone, then it is safe to omit any minimum thickness requirement; for to split into thin slabs with plug and feathers is expensive, and the contractor will surely not split the stone thinner than the maximum thickness specified. If the quarry stone is thin-bedded, as shaley limestone and some sandstones are, a minimum thickness of 3 or 4 ins. may be named. A maximum thickness of 10 or 12 ins. is a reasonable requirement. A minimum length of 12 ins. is often specified, and is not unreasonable, for slabs are readily broken with a hammer to almost any desired length. There is no objection to stones up to 24 ins. in length.

Slope-wall paving is "laid to break joint," as shown in Fig. 9, and it is well so to lay it, because if the toe is washed out, this breaking of joint enables the wall above to span the space, and so prevents rapid crumbling away of the wall. However, specifications are often drawn with absurd refinement as to this bonding; the least admissible number of inches of bond is named, and altogether the wall is treated as if it were to be a bridge pier, or arch, or other necessarily strong structure. To require that the stones shall be laid so as to beak joint is a sufficient requirement for slope-wall work.

We come now to the feature of the specifications that makes a wall cost little or much—the allowable maximum width of bed and end joints. Specifications sometimes name ½-in. joints to the full depth of each stone. Such work as we shall see costs twice as much as under the more reasonable requirement of 1½-in. joints, carried back 4 ins. from the face beyond which the stone may fall away to a wedge shape. To call for joints of less than 1½ ins. is justifiable only where well coursed slope-walling is desired for appearance sake. Wall with 1½-in. maximum joints serves the purpose of protection from erosion, and any expense incurred in better dressing is merely "for looks."

In laying a slope-wall, "frames" or "profiles" should be

set about 20 or 25 ft. apart, as shown in Fig. 10. Stakes are driven as shown, and a 1 × 4-in. profile-stick of timber is nailed to the stake at the proper grade, as determined by the Y-level. The workmen then stretch a string from the bottom of one frame to the bottom of the next one, and thus have a line to which they can accurately lay the face of the slope-wall. Never allow a workman to attempt to lay slope-wall without such frames and a cord to guide him; for without such guides he will surely lay a wall with humps and hollows. (See page 5 for hints on stint work on slope-walls.) Another point in practical laying is always to incline each stone lightly uphill. Do not try to set it exactly at right angles to the surface of the ground,

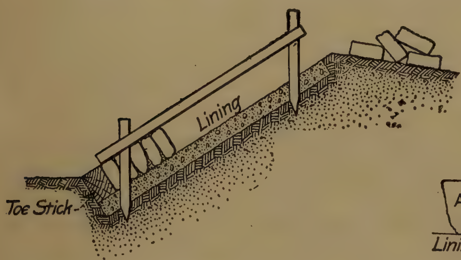


Fig. 10. Profile Frames Used in Slope Wall Laying.

Fig. 11. Improperly Laid Slope Wall.

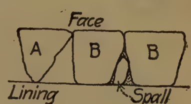


Fig. 12. Showing Proper and Improper Dressing of End Joints.

for an endeavor to do this results in a wall like that in Fig. 11, where the stone are in steps.

The stone are split with plug and feathers and hammers in the quarry, hauled by wagons and dumped at the top of the embankment, as in Fig. 10. Laborers then throw the stones down to the slope-wall masons, who roughly scabble and lay them, filling in the chinks back of the face with spalls and gravel lining. An intelligent laborer can soon learn to lay common slope-wall, but skilled slope-wall masons, if available, usually lay a better-appearing wall at less cost. Sharp-pointed stones like A, Fig. 12, should ordinarily not be allowed; but stones like B, that are roughly dressed, 3 to 4 ins. back of the face, and then fall away so as to leave a wide end joint as shown, are not objectionable, provided these joints are filled with spalls and gravel.

Before passing to a consideration of costs, a word should be given as to protecting the toe or foot of the wall. In canal work it is customary to lay a 12 × 12-in. toe-timber or stick, as shown in Fig. 10. Since timber continually submerged does not rot, and since frozen timber in the winter when canals are closed does not rot either, this design is not objectionable for canals. However, the writer questions the necessity of using a toe stick at all under ordinary conditions in canal work. In river work, a toe stick resting against piles driven 5 ft. c. to c., is often used. In some cases the toe stick is done away with entirely and a line of close-driven piles substituted, which is a very expensive solution of the problem and not altogether satisfactory. Piling on the concave bank of a river seems to hasten rather than retard undermining. A brush mattress is a better toe protection under such conditions, and heavy rip-rap is still better where the brush is alternately wet and dry.

The following are actual costs of work done by the writer: The quarry required very little stripping, and was located on a side hill, 2½ miles from the work. The stone was a thin bedded limestone, rather shaley, and was barred and wedged out with the use of little or no powder. There was very little plug and feathering as the stone split readily under the hammer. Common labor was employed, the only skilled man being the foreman, who worked with the men.

140 wagon loads of stone, each load measuring 2 cu. yds. corded upon the wagon, and 1.55 cu. yds. laid in the slope-wall, making a total of 220 cu. yds. in the wall, were quarried and loaded by five men (including the foreman) in 20 working days of 10 hours each, or at the rate of 2.2 cu. yds. of slope-wall quarried per man per day. Laborers received $1.50 a day and foreman $2.50, so the wages averaged $1.70, which, divided by 2.2, makes the cost nearly 80 cts. per cu. yd. for quarrying and loading the stone. Each driver helped load and unload his wagon, and hauled 4 to 5 loads a day. A team and driver received 70 cts. a load for hauling (5 miles round trip) over a good hard gravel road with no upgrades; so the cost of hauling was about 45 cts. per cu. yd. of slope-wall, making a total of

$1.25 for the stone delivered at the work. A quarry rental of 10 cts. per cu. yd. was paid for the stone. To estimate the cost of loading and hauling for other distances the following observations were made: Two laborers working quite deliberately handed up the stone to the driver, who stacked them on his "stone rack" (3 × 11 ft.), or wagon box without sides other than a strip of 4 × 4-in. timber. It required 15 mins. to load a wagon with 2 cu. yds. measured on the wagon, or 1.55 cu. yds. in the slope-wall. The driver alone would unload his wagon at the dump in 7 mins., by simply rolling the stone off.

The team traveled at a speed of 2½ miles an hour, or 220 ft. a minute, at a walk, and generally trotted part of the way back to make up for lost time at both ends. With a short haul, or over soft roads trotting would have been out of the question; and over very soft earth roads with occasional steep pulls a load half as great as the above is the maximum.

On another similar contract 750 cu. yds. of slope-wall were quarried at a cost of $1.10 per cu. yd., the stone being a "grit" or shaley limestone, quarried by laborers at $1.50 per day of 10 hours. The haul was 1¾ miles from quarry to wall and 6 trips a day were made by each team, hauling 1¾ cu. yds. each trip as measured in the wall, at a cost of 35 cts. per cu. yd. for hauling. This stone, therefore, cost $1.45 per cu. yd. delivered.

In laying 750 cu. yds. of "second-class" slope-wall, 12 ins. thick, joints 1½ ins. as a maximum, stone allowed to fall away 4 ins. back of face, not laid in courses, but an excellent wall in appearance and in reality, the cost was as follows: The first few days, using new hands, intelligent laborers, each man laid 2½ cu. yds. at a cost of 60 cts. a cu. yd., wages being $1.50 per 10-hour day. Later these men readily averaged 3 cu. yds. yer day. Some skilled slope-wall layers were imported and received $2.50 per 10-hour day. These men readily laid 5 cu. yds. each day, one laborer to every four slope-wall layers acting as a helper to deliver stone. Thus 600 cu. yds. of slope-wall were laid in 130 layer-days and 35 helper-days, half of the layers being skilled men, and half common laborers. There was

no foreman in constant attendance, as each man's work between the frames was easily measured up, and his daily progress thus known. A portion of the work was sublet at 50 cts. per cu. yd. to two of the skilled slope-wall masons who had each been averaging 5 cu. yds. a day. From that time on each averaged 7½ cu. yds. of wall daily! Skilled men like these under subcontract will lay 10 or even 12 cu. yds. of a somewhat rougher slope-wall in 10 hours. On another contract where the wall was 16 ins. thick, 4 masons at $2.50 and 4 laborers at $1.50 averaged 60 cu. yds. of fair slope-wall per 10-hour day. Work was scarce, and one of the masons was the subcontractor himself, and received 30 cts. per cu. yd. Assuming 50 cts. per cu. yd. as a fair average cost for laying good "second-class" slope-wall and $1.25 to $1.50 for cost of stone delivered, we have a total cost of $1.75 to $2.00 per cu. yd. in place.

The average contract price for slope-wall on the Erie Canal deepening in 1896-7 was $2.50 per cu. yd., wages being as above given. Slope-wall laid in courses, with close joints the full depth of the wall, no course less than 6 ins. thick—a sand-papered job—was let for $4.50 per cu. yd. under conditions where $2.50 was a fair price for good ordinary slope-wall. The actual cost was not far below the contract price for stone plug and feathered to size cost delivered $2.50 per cu. yd., and laying cost $1.25 per cu. yd. Gravel lining in both cases was paid for separately, the contract price along the Erie Canal averaging 90 cts. per cu. yd. of lining in place. The actual cost of this lining is of course figured as for any earthwork, an allowance being made for spreading it on the face of the embankment after dumping it. To spread it most expeditiously it will pay to make a wooden chute into which the gravel is shoveled from the wagons, a shoveler helping the driver to unload. Two men will unload 1 cu. yd. in this way in 10 minutes, if they work as they should. The driver then has a rest on his return trip, at the end of which it is well to provide an extra wagon, which has been loaded during his absence. It takes only 1½ mins. to change the team from the empty to the loaded wagon. Since 1 to 1¼ cu. yds. of gravel constitute a load, since teams travel 220 ft. per min.,

and since a laborer can load 18 cu. yds. of gravel in 10 hrs., we have all the factors necessary to compute the cost of hauling and unloading. There is very little work in spreading the gravel where a chute is used, 2 to 5 cts. per cu. yd. covering this item.

If good thin-bedded sandstone or limestone is not available, it may be necessary to plug and feather the stone to sizes specified, and this cost may be estimated by data on page 203.

Cost of a Granite Slope-Wall.—The cost of a granite slope-wall greatly exceeds the cost of slope-walls of stratified rock such as are described in the preceding paragraphs, if any attempt is made to square the granite slope-wall stones, for rubble granite stones must be plug and feathered on all faces to square them up. Even where the specifications are lenient, if an attempt is made to secure a granite slope-wall with a smooth face, but without close joints, the cost of plugging off the faces of stone before laying, and the cost of reducing them to a size not greater than the thickness of the wall (12 to 18 ins.) is not a small item. If granite boulders, or granite rubble stones from a quarry, are to be used, first estimate roughly the average size of each stone, then estimate the number of plug-holes necessary to split it into slope-wall stones. Use the data on page 203 for estimating the cost of this plug and feather work.

On one job of granite slope-wall work, 3 masons splitting field boulders with plugs, and 10 laborers laying a wall 18 ins. thick, averaged 14 cu. yds. per day of 10 hrs. for $24, or $1.70 per cu. yd. for splitting and laying the stones. No attempt was made to secure close joints or to lay the stone in courses. Stones were frequently laid flatwise and bedded in spawls; and spawls were used liberally between joints. The masons were rapid workers, but the laborers were a slow lot of men.

Cost of Laying a Limestone Slope-Wall.—Mr. W. B. Fuller in Trans. Am. Soc. C. E., Vol. 43, 1900, p. 303, says: "The paving of the apper sides of the sedimentation basin (Albany, N. Y.) is of blue limestone blocks, 10 to 15 ins. deep,

8 to 20 ins. wide, and 15 to 36 ins. long. Two masons and one helper together would lay about 16 sq. yds. per day, and the labor cost of laying the stone and gravel, including the teaming of the material about 800 ft., was 72 cts. per sq. yd."

The specifications called for a slope-wall 10 ins. thick laid on a gravel lining 24 ins. thick.

Cost of Excavating Masonry.—The masonry abutments of an old bridge were removed to make way for a new arch bridge. A hand-power derrick was used, and the material was piled near the derrick. The cost of excavating this masonry was 50 cts. per cu. yd., wages being 15 cts. per hr. In another similar case the cost was 75 cts. per cu. yd. The average contract price for such work on the Erie Canal, in 1896, was 80 cts. per cu. yd., wages being 12½ cts. per hr.

Mr. C. R. Neher, M. Am. Soc. C. E., informs me that the cost of excavating 3,140 cu. yds. of old railway bridge piers, and depositing the material in the river bed, was 38 cts. per cu. yd., not including the cost of scaffolding.

Cost of Pointing Old Bridge Masonry.—Cleaning and pointing old masonry, using Alpha cement at $2.40 per bbl., masons wages being $2 and helpers $1.60 per day, cost as follows:

Small jobs; no staging:	Cts. per sq. ft.
Cement	0.26
Labor	0.74
Total per sq. ft.	1.00

This is equivalent to 9 cts. per sq. yd.

Large jobs; staging used:	Cts. per sq. ft.
Cement	0.27
Labor	1.87
Total per sq. ft.	2.14

This is equivalent to 19 cts. per sq. yd.

Cost of Lining Tunnels.—Drinker gives the following data on the lining of Carr's Tunnel (825 ft.) on the Pennsylvania R. R. in 1868-1869. Brickwork: 609,000 brick in the arch (5% broken and lost); 10.44 bushels of neat cement (no sand used in the mortar) laid 1,000 bricks, the mortar forming 30% of the brick masonry; the arch was 25 ft. thick, 24½-ft. span and 9-ft. rise:

	Cost per M.
Bricks f. o. b.	$8.80
Loss in handling	0.51
Unloading and delivering	1.92
Laying	5.84
Cement	5.10
Total	$22.17

Bricklayers received 40 cts. per hr.; helpers, 17½ cts. per hr.; carpenters, 27½ cts. per hr.; laborers, 17 cts. per hr.

Stonework: 1,730 perches (25 cu. ft.) of rough masonry for side walls, presumably sandstone; 187 perches of ring stone; 25 perches wasted in dressing. The bench walls were 4 ft. wide at the bottom, 3 ft. at the top and 13 ft. high:

	Cost per perch.
Quarrying (1,730 perches)	$4.80
Cutting (1,730 perches)	4.36
Hauling (1,942 perches)	1.06
Handling and laying (1,917 perches)	2.80
Cement, 1.65 bu. per perch (8 1-6% of the masonry)	0.81
Total	$13.83

Stone cutters and masons received 35 cts. per hr.; quarrymen, 17½ cts.; laborers, 17 cts. The stone side walls were laid in 8 courses averaging 2 ft. thick each; hence there were 52,800 sq. ft. of beds cut; and estimating each stone 3 ft. long and dressed for 1½ ft. back of the face on joints, there were 14,300 sq. ft. of joints; making a total of 67,100 sq. ft. of cutting which cost 11.2 cts. per

sq. ft. This is said to have been too high a cost, if the measurements were correct.

Arch centering cost $1,400, to which was added $600 for moving the centering forward from time to time; making $2.40 per lin. ft. of tunnel, to which must be added $0.70 per ft. for scaffolding.

In Engineering News, Oct. 25, 1894, is given an abstract of a paper read before the Montana Society of C. E.'s, by Mr. H. C. Relf, on the lining of the Mullan Tunnel on the Northern Pacific Ry. with masonry to replace timber. The tunnel is 3,850 ft. long, 20 miles west of Helena. Falls of rock and fires in the tunnel had caused numerous delays. The original timbering consisted of sets 4 ft. c. to c. of 12 × 12-in. timbers, with 4-in. lagging. The size was 16 × 20 ft. in the clear.

Concrete side walls (30-in.) and four-ring brick arch were built in place of the old timbering. A 7-ft. section was first prepared by removing one post and supporting the arch by struts. Two temporary posts were set up and fastened by hook bolts; and a lagging was placed back of them to make forms to hold the concrete. Several of these 7-ft. sections were prepared at a time, each two being separated by a 5-ft. section of the old timbering. The mortar car delivered Portland cement mortar (1 to 3) through a chute, making an 8-in. layer of mortar into which broken stone was shoveled until all the mortar was taken up by the stone voids. In 10 to 14 days the walls were hard enough to support the arches which were then allowed to rest on the walls, and the posts of the remaining 5-ft. sections were removed, and concrete placed as before. About 4 parts of mortar were used to 5 parts of broken stone, which is a very rich concrete. The average progress per working day was 30 ft. of side wall, or 45 cu. yds.; and the average cost, including removal of old timber, train service, engineering, superintendence and interest on plant, was $8 per cu. yd. of concrete wall. From 3 to 9 ft. of brick arch was put in at a time, depending upon the nature of the ground. To remove the old timber arch one of the segments was partly sawed through, and a small charge of dynamite exploded in it; the debris

being caught on a platform car, from which it was removed to another car and conveyed away. The center was then placed, and the cement car used to mix mortar on. Brick were $2\frac{1}{2} \times 4\frac{1}{2} \times 9$ ins., four ringings, making a 20-in. arch and giving 1.62 cu. yds. per lin. ft. of tunnel. The bricks were laid in rowlock bond. Two gangs of 3 bricklayers and 6 helpers each, laid 12 lin. ft., or 19.4 cu. yds., of brick arch per day. The brick work cost $17 per cu. yd., making the total cost of tunnel lining $50 per lin. ft. The work was still in progress at the time of writing.

SECTION VI.

COST OF CONCRETE CONSTRUCTION OF ALL KINDS.

Definitions.—*Concrete* is an artificial stone made by mixing cement mortar with gravel or broken stone. The proportions of cement, sand and stone are generally expressed in parts by measure (occasionally by weight). A 1:2:5 (one, two, five) concrete means 1 part cement to 2 parts sand to 5 parts stone. A 1:3:6 concrete is made of 1 part cement, 3 parts sand and 6 parts stone (or gravel). When both stone and gravel are used, the concrete may be designated thus, 1:3:2:4, which means 1 part cement, 3 parts sand, 2 parts gravel and 4 parts stone.

Dry Concrete is a term used to designate a mixture containing so small a percentage of water that very hard ramming is required to flush the water to the surface.

Wet Concrete contains so much water as to require little or no ramming. "Sloppy concrete" is concrete so wet that it will run down a slightly inclined trough.

Natural cement is a term applied to the cheap brands of hydraulic cement made by calcining and grinding a limestone containing naturally enough clayey matter to make a cement that will harden under water. A few years ago it was common practice to give to all natural cements the name Rosendale cement, for it was at Rosendale, N. Y. that the first natural cement was made in this country.

Portland cement is a term applied to a cement made by calcining and grinding a mixture of about 1 part clay to 4 parts limestone, the temperature being so high that the clay combines chemically with the lime, leaving little or no quicklime.

Slag cement is a cement made by mixing powdered slaked lime and pulverized blast-furnace slag. It will harden under water.

Ballast is a term used to designate the broken stone or

gravel used in making concrete. The term *aggregate* is often used instead of ballast. English writers use the word *shingle* instead of gravel. The terms *crushed stone* and *broken stone* are used indiscriminately to designate stone that has been broken by a rock crusher. *Screenings* applies to the product of the crusher that passes through the smallest screen used. The size of the smallest hole in the screen varies from ⅛-in. to ¾-in., so the word screenings has no definite meaning, although it can usually be taken to apply to all stone under ½-in. in diameter.

Crusher run means all the crushed stone just as it comes from the crusher, without separation into sizes, and generally it includes the product that would be termed screenings if it were screened out.

Matrix is a term sometimes used instead of mortar, but there is no good reason for using the term at all.

A *batch* of concrete is the amount mixed at one time either by a gang of men or by a machine mixer. In hand mixing, ordinarily one barrel of cement and the proper proportions of sand and stone make a batch.

Forms are the *molds* (usually of lumber) that hold the concrete in shape until it has *set* or hardened.

Concrete that is mixed *dry* is spread in layers 6 or 8 ins. thick and *rammed* or *tamped* until the water flushes to the surface. Concrete that is mixed *wet* is *spaded* with a spade-like tool that is worked upon and down in the concrete to remove all air bubbles particularly near the forms or near any steel used to *reinforce* the concrete.

Reinforced concrete is concrete in which are embedded bars or wires of steel or iron. It is often called *concrete-steel*, especially by workmen and contractors.

Rubble concrete is a term applied to concrete in which large rubble stones, or *plums*, are embedded. Stones from the size of a man's head to the size of a barrel are thus used. When larger stones are used, and the concrete becomes simply a coarse grained mortar between them, probably the term *cyclopean masonry* is more correct than *rubble concrete*; still there is no distinct dividing line.

Voids is a term applied to the spaces between the grains of sand, or to the spaces between the fragments of broken stone. The voids are expressed in a percentage of the total volume of the loose material.

Theory of the Quantity of Cement in Mortar and Concrete.—All sand contains a large percentage of voids. In 1 cu. ft. of loose sand there are 0.3 to 0.5 cu. ft. of voids; that is, 30% to 50% of the sand is voids. In making mortar the cement is mixed with the sand, and the flour-like grains of the cement fit in between the grains of the sand, occupying a part or all of the voids in the sand. According to the old theory (as given in Trautwine's Handbook and elsewhere), the amount of cement required to make a given mortar is calculated as follows: Suppose the mortar is to be 1 cu. ft. of cement to 2 cu. ft. of sand (a 1 to 2 mortar); and suppose the sand contains 35% voids, then 2 cu. ft. of sand would contain 2 × 0.35; or 0.7 cu. ft. voids. Now, the 1 cu. ft. of cement would fill this 0.7 cu. ft. of voids in the sand and leave an excess of 1 — 0.7, or 0.3 cu. ft. of cement; hence, the resulting mortar would be 2 cu. ft. of sand + 0.3 cu. ft. of cement (the excess left over after filling the voids in the sand), thus making 2.3 cu. ft. of mortar from the mixture of 1 cu. ft. of cement with 2 cu. ft. of sand. As above stated, this simple theory was commonly given by all writers (without exception, so far as I know), although many contractors and some engineers must have learned by experience that the theory is incorrect. In Engineering News, Dec. 5, 1901, I called public attention to the errors of the theory. In the same article a theory that gives much closer approximations to the truth was outlined.

Since a correct estimate of the number of barrels of cement per cubic yard of mortar or concrete is very important, and since it is not always possible to make actual mixtures before bidding, it seems wise to give space to a discussion of the theory that I have offered.

When loose sand is mixed with water, its volume or bulk is increased; subsequent jarring will decrease its volume, but still leave a net gain of about 10%; that is, 1 cu. ft. of dry sand becomes about 1.1 cu. ft. of damp sand. Not only does this increase in the volume of the sand occur, but, instead of increasing the voids that can be filled with cement, there is an absolute loss in the volume of available voids. This is due to the space occupied by the water necessary to bring the sand to the consistency of mortar; furthermore, there is seldom a perfect mixture of the sand and cement

in practice, thus reducing the available voids. It is safe to call this reduction in available voids about 10%.

When loose, dry Portland cement is wetted, it shrinks about 15% in volume, behaving differently from the sand, but it never shrinks back to quite as small a volume as it occupies when packed tightly in a barrel. Since barrels of different brands vary widely in size, the careful engineer or contractor will test any brand he intends using in large quantities, in order to ascertain exactly how much cement paste can be made. He will find a range of from 3.2 cu. ft. to 3.8 cu. ft. per bbl. of Portland cement. Obviously the larger barrel may be cheaper though its price is higher. Specifications often state the number of cubic feet that will be allowed per barrel in mixing the concrete ingredients, so that any rule or formula to be of practical value must contain a factor to allow for the specified size of the barrel, and another factor to allow for the actual number of cubic feet of paste that a barrel will yield—the two being usually quite different.

The deduction of a rational, practical formula for computing the quantity of cement required for a given mixture will now be given, based upon the facts above outlined.

Let p = number of cu. ft. cement paste per bbl., as determined by actual test.

n = number of cu. ft. of cement per bbl., as specified in the specifications.

s = parts of sand (by volume) to one part of cement, as specified.

g = parts of gravel or broken stone (by volume) to one part of cement, as specified.

v = percentage of voids in the dry sand, as determined by test.

V = percentage of voids in the gravel or stone, as determined by test.

Then, in a mortar of 1 part cement to s parts sand, we have:

$n\,s$ = cu. ft. of dry sand to 1 bbl. cement.

$n\,s\,v$ = " " " voids in the dry sand.

$0.9\,n\,s\,v$ = " " " available voids in the wet sand.

$1.1\,n\,s$ = " " " wet sand.

$p - 0.9\,n\,s\,v$ = " " " cement paste in excess of the voids.

Therefore:

$$1.1\ n\ s + (\ p - 0.9\ n\ s\ v) = \text{cu. ft. of mortar per bbl.}$$

Therefore:

$$N = \frac{27}{1.1\ n\ s + (p - 0.9\ n\ s\ v)} = \frac{27}{p + n\ s\ (1.1 - 0.9\ v)}$$

N being the number of barrels of cement per cu. yd. of mortar.

When the mortar is made so lean that there is not enough cement paste to fill the voids in the sand, the formula becomes

$$N = \frac{27}{1.1\ n\ s}$$

A similar line of reasoning will give us a rational formula for determining the quantity of cement in concrete; but there is one point of difference between sand and gravel (or broken stone), namely, that the gravel does not swell materially in volume when mixed with water. However, a certain amount of water is required to wet the surface of the pebbles, and this water reduces the available voids, that is, the voids that can be filled by the mortar. With this in mind, the following deduction is clear, using the nomenclature and symbols above given:

ng = cu. ft. of dry gravel (or stone).
ng V = " " " voids in dry gravel.
0.9 ng V = " " " "available voids" in the wet gravel.
p + n s (1.1 — 0.9 v) — 0.9 ng V = excess of mortar over the available voids in the wet gravel.
ng + p + n s (1.1 — 0.9 v) — 0.9 ng V = cu. ft. of concrete from 1 bbl. cement.

$$N = \frac{27}{p + n\ s\ (1.1 - 0.9\ v) + ng\ (1 - 0.9\ V)}$$

N being the number of barrels of cement required to make 1 cu. yd. of concrete.

This formula is rational and perfectly general. Other experimenters may find it desirable to use constants slightly

different from the 1.1 and the 0.9, for fine sands swell more than coarse sands, and hold more water.

The reader must bear in mind that when the voids in the sand exceed the cement paste, and when the available voids in the gravel (or stone) exceed the mortar, the formula becomes:

$$N = \frac{27}{ng}$$

These formulas give the amounts of cement in mortars and concretes compacted in place. Tables V. to VIII. are based upon the foregoing theory, and will be found to check satisfactorily with actual tests.

TABLE V.

Barrels of Portland Cement per Cubic Yard of Mortar.

(Voids in sand being 35%, and 1 bbl. cement yielding 3.65 cu. ft. of cement paste.)

Proportion of Cement to sand.	1 to 1	1 to $1\frac{1}{2}$	1 to 2	1 to $2\frac{1}{2}$	1 to 3	1 to 4
	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.
Barrel specified to be 3.5 cu. ft......	4.22	3.49	2.97	2.57	2.28	1.76
" " 3.8 "	4.09	3.33	2.81	2.45	2.16	1.62
" " 4.0 "	4.00	3.24	2.73	2.36	2.08	1.54
" " 4.4 "	3.81	3.07	2.57	2.27	2.00	1.40
Cu. yds. sand per cu. yd. mortar....	0.6	0.7	0.8	0.9	1.0	1.0

TABLE VI.

Barrels of Portland Cement per Cubic Yard of Mortar.

(Voids in sand being 45%, and 1 bbl. cement yielding 3.4 cu. ft. of cement paste.)

Proportion of Cement to Sand.	1 to 1	1 to $1\frac{1}{2}$	1 to 2	1 to $2\frac{1}{2}$	1 to 3	1 to 4
	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.
Barrel specified to be 3.5 cu. ft......	4.62	3.80	3.25	2.84	2.35	1.76
" " 3.8 "	4.32	3.61	3.10	2.72	2.16	1.62
" " 4.0 "	4.19	3.46	3.00	2.64	2.05	1.54
" " 4.4 "	3.94	3.34	2.90	2.57	1.86	1.40
Cu. yds. sand per cu. yd. mortar....	0.6	0.8	0.9	1.0	1.0	1.0

In using these tables remember that the proportion of cement to sand is by volume, and not by weight. If the spec-

ifications state that a barrel of cement shall be considered to hold 4 cu. ft., for example, and that the mortar shall be 1 part cement to 2 parts sand, then 1 barrel of cement is mixed with 8 cu. ft. of sand, regardless of what is the actual size of the barrel, and regardless of how much cement paste can be made with a barrel of cement. If the specifications fail to state what the size of a barrel will be, then the contractor is left to guess.

If the specifications call for proportions by weight, assume a Portland barrel to contain 380 lbs. of cement, and test the actual weight of a cubic foot of the sand to be used. Sand varies extremely in weight, due both to the variation in the per cent of voids, and to the variation in the kind of minerals of which the sand is composed. A quartz sand having 35% voids weighs 107 lbs. per cu. ft.; but a quartz sand having 45% voids weighs only 91 lbs. per cu. ft. If the weight of the sand must be guessed at, assume 100 lbs. per cu. ft. If the specifications require a mixture of 1 cement to 2 of sand by weight, we will have 380 lbs. (or 1 bbl.) of cement mixed with 2 × 380, or 760 lbs. of sand; and if the sand weighs 90 lbs. per cu. ft., we shall have 760 ÷ 90, or 8.44 cu. ft. of sand to every barrel of cement. In order to use the tables above given, we may specify our own size of barrel; let us say 4 cu. ft.; then 8.44 ÷ 4 gives 2.11 parts of sand by volume to 1 part of cement. Without material error we may call this a 1 to 2 mortar, and use the tables, remembering that our barrel is now "specified to be" 4 cu. ft. If we have a brand of cement that yields 3.4 cu. ft. of paste per bbl., and sand having 45% voids, we find that approximately 3 bbls. of cement per cu. yd. of mortar will be required.

It should be evident from the foregoing discussions that no table can be made, and no rule can be formulated that will yield accurate results unless the brand of cement is tested and the percentage of voids in the sand determined. This being so the sensible plan is to use the tables merely as a rough guide, and, where the quantity of cement to be used is very large, to make a few batches of mortar using the available brands of cement and sand in the proportions specified. Ten dollars spent in this way may save a thousand, even on a comparatively small job, by showing what cement and sand to select.

TABLE VII.*

Ingredients in 1 Cubic Yard of Concrete.

(Sand voids, 40%; stone voids, 45%; Portland cement barrel yielding 3.65 cu. ft. paste. Barrel specified to be 3.8 cu. ft.)

Proportions by Volume.	1:2:4	1:2:5	1:2:6	1:2½:5	1:2½:6	1:3:4
Bbls. cement per cu. yd. concrete	1.46	1.30	1.18	1.13	1.00	1.25
Cu. yds. sand " "	0.41	0.36	0.33	0.40	0.35	0.53
Cu. yds. stone " "	0.82	0.90	1.00	0.80	0.84	0.71
Proportions by Volume.	1:3:5	1:3:6	1:3:7	1:4:7	1:4:8	1:4:9
Bbls. cement per cu. yd. concrete	1.13	1.05	0.96	0.82	0.77	0.73
Cu. yds. sand " "	0.48	0.44	0.40	0.46	0.43	0.41
Cu. yds. stone " "	0.80	0.88	0.93	0.80	0.86	0.92

*This table is to be used where cement is measured packed in the barrel, for the ordinary barrel holds 3.8 cu. ft.

It will be seen that the above table can be condensed into the following rule: Add together the number of parts and divide this sum into ten, the quotient will be approximately the number of barrels of cement per cubic yard. Thus for a 1:2:5 concrete, the sum of the parts is 1 + 2 + 5, which is 8; then 10 ÷ 8 is 1.25 bbls., which is approximately equal to the 1.30 bbls. given in the table. Neither this rule nor this table is applicable if a different size of cement barrel is specified, or if the voids in the sand or stone

TABLE VIII.

Ingredients in 1 Cubic Yard of Concrete.

(Sand voids, 40%; stone voids, 45%; Portland cement barrel yielding 3.65 cu. ft. of paste. Barrel specified to be 4.4 cu. ft.)

Proportions by Volume.	1:2:4	1:2:5	1:2:6	1:2½:5	1:2½:6	1:3:4
Bbls. cement per cu. yd. concrete	1.30	1.16	1.00	1.07	0.96	1.08
Cu. yds. sand " "	0.42	0.38	0.33	0.44	0.40	0.53
Cu. yds. stone " "	0.84	0.95	1.00	0.88	0.95	0.71
Proportions by Volume.	1:3:5	1:3:6	1:3:7	1:4:7	1:4:8	1:4:9
Bbls. cement per cu. yd. concrete	0.96	0.90	0.82	0.75	0.68	0.64
Cu. yds. sand " "	0.47	0.44	0.40	0.49	0.44	0.42
Cu. yds. stone " "	0.78	0.88	0.93	0.86	0.88	0.95

NOTE.—This table is to be used when the cement is measured loose, after dumping it into a box, for under such conditions a barrel of cement yields 4.4 cu. ft. of loose cement.

differ materially from 40% and 45% respectively. There are such inumerable combinations of varying voids, and varying sizes of barrel, that the author does not deem it worth while to give other tables.

Cement per Cubic Yard of Mortar By Test.

According to tests by Sabin, by Fuller (in Taylor and Thompson) and by H. P. Boardman, the following results were obtained:

Authority.	Neat.	1 to 1	1 to 2	1 to 3	1 to 4	1 to 5	1 to 6	1 to 7	1 to 8
	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.
Sabin............	7.40	4.17	2.84	2.06	1.62	1.33	1.14	....	....
W. G. Fuller......	8.02	4.58	3.09	2.30	1.80	1.48	1.23	1.11	1.00
H. P. Boardman..	7.40	4.50	3.18	2.35	....	....	....	....	....

The proportions were by barrels of cement to barrels of sand, and Sabin called a 380-lb. barrel 3.65 cu. ft., whereas Fuller called a 380-lb. barrel 3.80 cu. ft.; and Boardman called a 380-lb. barrel 3.5 cu. ft. Sabin used a sand having 38% voids; Fuller used a sand having 45% voids; and Boardman used a sand having 38% voids. It will be seen that the cement used by Sabin yielded 3.65 cu. ft. of cement paste per bbl. (i. e. 27 ÷ 7.4), whereas the (Atlas) cement used by Fuller yielded 3.4 cu. ft. of cement paste per bbl. Sabin found that a barrel of cement measured 4.37 cu. ft. when dumped and measured loose.

Mr. Boardman states a barrel (380 lbs., net) of Lehigh Portland cement yields 3.65 cu. ft. of cement paste; and that a barrel (265 lbs., net) of Louisville natural cement yields 3.0 cu. ft. of cement paste.

Mr. J. J. R. Croes, M. Am. Soc. C. E., states that 1 bbl. of Rosendale cement and 2 bbls. of sand (8 cu. ft.) make 9.7 cu. ft. of mortar, the extreme variations from this average being 7%.

The Size and Weight of Barrels of Cement.—A barrel of Portland cement contains 380 lbs. of cement, and the barrel itself weighs 20 lbs. more. The size of the barrel varies considerably, due to the difference in weight per struck bushel, and to the difference in compressing the cement in the barrel. A light burned Portland cement weighs 100 lbs. per struck bushel; a heavy burned cement weighs 118 to 125 lbs. per struck bushel. The number of

cubic feet of packed Portland cement in a barrel ranges from 3 to 3½. English Portland cement barrels contain 3⅓ to 3½ cu. ft. packed. There are usually four bags (cloth sacks) of cement to the barrel, and each bag itself weighs 1½ lbs.

The natural cements are lighter than Portland. The Western cements, such as Louisville, Akron and Utica weigh 265 lbs. per bbl., and the barrel weighs 15 lbs. more. A barrel of Louisville cement = 3¾ cu. ft. packed. The Rosendale cements of New York and Pennsylvania weigh 300 lbs. per bbl. and the barrel weighs 20 lbs. more. There are usually three bags of natural cement to the barrel.

When cement is ordered in cloth sacks, there is a charge made of 10 cts. per sack, but on return of the sacks a credit of 8 to 10 cts. per sack is allowed. Cement ordered in wooden barrels costs 10 cts. more per bbl. than in bulk. Cement ordered in paper bags costs 5 cts. more per bbl. than in bulk. Hence it is that nearly all cement used in large quantities is ordered in cloth sacks which are returned.

When a barrel of cement is dumped out and shoveled into a box it measures much more than when packed in the barrel, ordinarily from 20 to 30% more. I have measured a number of barrels of English Portland cement, which is still much used on the Pacific Coast of America, and find that a barrel having a capacity of 3¾ cu. ft. between heads will yield 4.5 cu. ft. of cement measured dry and loose in a box. I have found brands of American Portland cement that yield 4.65 cu. ft. when measured loose in a box. The variation is considerable, as is seen in the following table, compiled from data given by Mr. Howard Carson, M. Am. Soc. C. E.:

Brand of Portland cement.	(1) Capacity of bbl. Cu. ft.	(2) Actual contents of packed bbl. Cu. ft.	(3) Volume when dumped loose. Cu. ft.	Increase in bulk.
Giant..................	3.5	3.35	4.17	25%
Atlas....................	3.45	3.21	3.75	18%
Saylor's	3.25	3.15	4.05	30%
Alsen (German)........	3.22	3.16	4.19	33%
Dyckerhoff (German)..	3.12	3.03	4.00	33%

Some engineers require the contractor to measure the sand and stone in the same sized barrel that the cement

comes in; then 1 part of sand or stone usually means 3½ cu. ft. Other engineers permit both heads of the barrel to be knocked out, for convenience in measuring the sand and stone; then a barrel means about 3¾ cu. ft. Still other engineers permit the contractor to measure his cement in a box, loose; then a barrel usually means from 4 to 4.5 cu. ft. Since most of the cement now used is shipped in bags and since four bags of Portland cement make a barrel, it is the custom among many engineers to call a bag 1 cu. ft., even though it may yield a little more cement. Still other engineers prefer to specify that a Portland barrel shall be called 3.8 cu. ft., which is equivalent to 100 lbs. of cement per cu. ft.

It is desirable that engineers and architects adopt some uniform practice in this matter, for now a contractor is often unable to estimate the quantity of cement required for any specified mixture because the size of the barrel is not specified.

There have been advocates of proportioning parts by weight, but, aside from the fact that it is seldom convenient to weigh the ingredients of every batch, there is no gain in such a departure from long standing precedent. Sand and gravel and stone are by no means constant in specific gravity, as advocates of weighing seem to suppose.

Effect of Moisture on Voids in Sand.—Few engineers and fewer contractors realize how greatly the volume of sand is affected by the presence of varying percentages of moisture in the sand. A dry, loose sand that has 45% voids if mixed with 5% (by weight) of water will swell (unless tamped) to such an extent that its voids may be 57%. The same sand, if saturated with more water until it becomes a thin paste, may show only 37½% voids after the sand has settled. The following tests by Feret show the effect that water has upon sand:

Two kinds of sand were used, a very fine sand and a coarse sand. They were measured in a box that held 2 cu. ft., and was 8 ins. deep, the sand being shoveled into the box, but not tamped or shaken. After measuring and weighing the dry sand, 0.5% (by weight) of water was added, the sand was mixed and shoveled into the box again and weighed. This was repeated with varying percentages of water, up to 10%, with the following results:

Per cent. of water in sand	0%	0.5%	1%	2%	3%	5%	10%
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight per cu. yd. of fine sand and water	3,457	2,206	2,085	2,044	2,037	2,035	2,133
Weight per cu. yd. of coarse sand & water	2,551	2,466	2,380	2,122	2,058	2,070	2,200

It will be noted that the weight of mixed sand and water is given; but, to ascertain the exact weight of dry sand in the mixture, divide the weight given in the table by 100% plus the given tabular %; thus, the weight of dry fine sand mixed with 5% of water is 2,035 ÷ 1.05 = 1,938 lbs. per cu. yd. It will also be noted that when the water exceeds 3 to 5%, the weight of the mixture increases, showing that a larger percentage of water compacts the sand. The voids in the dry fine sand were 45%, and in the sand with 5% moisture they were 56.7%.

It is well known that pouring water onto loose, dry sand compacts it. By mixing fine sand and water to a thin paste, pouring it into a pail and allowing it to settle, it was found that the sand occupied 11% less space than when measured dry in a box. The voids in fine sand, having a specific gravity of 2.65, were determined by measurements in a quart measure, and found to be as follows:

	Voids.
Sand, not packed	44½%
" shaken to refusal	35 %
" saturated with water	37½%

Mr. H. P. Boardman made some experiments with Chicago sand having 34 to 40% voids when dry, by adding water to the sand. The results were as follows:

	%	%	%	%	%
Water added, % by weight	2	4	6	8	10
Resulting increase in volume	17.6	22	19.5	16.6	15.6

However, a very moderate amount of shaking would reduce this increase in volume by ⅓ to ½.

Effect of Size of Sand Grains on Voids.—If in any given volume of sand all the grains were of the same shape and of uniform size, the percentage of voids would be the same, regardless of the size of the grains. This is equivalent to saying that the finest birdshot has the same percentage of voids as the coarsest buckshot. Natural sand grains,

unless they have been sorted by screening, are apt to vary greatly in size, large and small being intermixed. It is this that causes such wide discrepancies in published data as to the percentage of voids in dry bank sands. We may divide sand into three sizes, for convenience. The largest size (L) being sand that will pass a sieve of 5 meshes per lineal inch, but will not pass a sieve of 15 meshes per lineal inch; the medium size (M) being sand that will pass a 15 mesh sieve, but will not pass a sieve of 50 meshes per lineal inch; and the fine size (F) being sand that will pass a 50-mesh sieve. If we mix varying proportions of the large, medium and fine (L, M and F), we find that we get the densest mixture, with the least voids, when we have a L6, M0. F4 mixture, that is, 6 parts large size, no parts medium, and 4 parts fine size. With a dry sand whose grains have a specific gravity of 2.65, if we weigh a cubic yard of either the fine, or the medium, or the large size, we find a weight of 2,190 lbs. per cu. yd., which is equivalent to 51% voids. If we mix the three different sizes in varying proportions, we find, as above stated, that an L6, M0, F4 mixture is densest, and it weighs 2,840 lbs. per cu. yd. shoveled into a box dry. This is equivalent to 36% voids. We can get a denser mixture, with a lower percentage of voids, if we mix about equal parts of sand and clean gravel. It will be noted that the common statement that the densest mixture is obtained by a mixture of gradually increasing sizes of grains is erroneous. There must be enough difference in the sizes of grains to provide voids so large that the smaller grains will enter them and not wedge the larger grains apart.

The shape of the grains has a very pronounced effect upon the percentage of voids, rounded grains having less voids than angular grains. Using sand having a granulometric composition of L5, M3, F2, measured in a quart measure, the following results were obtained by Feret:

	Voids.	
	Unshaken	Shaken.
Natural sand, rounded grains	35.9%	25.6%
Crushed quartzite, angular grains	42.1	27.4
Crushed shells, flat grains	44.3	31.8
Residue of quartzite, flat grains	47.5	34.6

The measure was shaken until no further settlement could be produced.

Mr. William B. Fuller made the following tests: A dry sand, having 34% voids shrank 9.6% in volume upon thorough tamping, until it had 27% voids. The same sand moistened with 6% water, and loose, had 44% voids, which was reduced to 31% by ramming. The same sand saturated with water had 33% voids, and by thorough ramming its volume was reduced 8½%, until the sand had only 26½% voids.

TABLE IX.—Sizes of Sand Grains.

Held by a Sieve	A	B	C	E
No. 10..........	35.3%	....	....	....
No. 20..........	32.1	12.8%	4.2%	11%
No. 30..........	14.6	49.0	12.5	14
No. 40..........	....	....	44.4	....
No. 50..........	9.6	29.3	....	53
No. 100.........	4.9	5.7	....	....
No, 200.........	2.0	2.3	....	....
Voids	33%	39%	41.7%	31%

NOTE.—A is a "fine gravel" (containing 8% clay) used at Philadelphia. B, Delaware River sand. C, St. Mary's River sand. D, Green River, Ky., sand, "clean and sharp."

TABLE X.—Voids in Sand.

Locality	Authority	Voids	Remarks
Ohio River...........	W. H. Hall	31%	Washed
Sandusky, O.........	C. E. Sherman	40%	Lake
Franklin Co., O......	C. E. Sherman	40%	Bank
Sandusky Bay, O....	S. B. Newberry	32.3%	....
St. Louis, Mo........	H. H. Henby	34.3%	Miss. River
Sault Ste. Marie.....	H. von Schon	41.7%	River
Chicago, Ill..........	H. P.Boardman	34 to 40%	....
Philadelphia, Pa....	....	39%	Del. River
Mass. Coast..........	....	31 to 34%	....
Boston, Mass........	Geo A. Kimball	33%	Clean
Cow Bay, L. I........	Myron S. Falk	40½%	....
Little Falls, N. J....	W. B. Fuller	45.6%	....
Canton, Ill...........	G. W. Chandler	30%	Clean

Voids in Broken Stone and Gravel.—The percentage of voids in loose, broken stone depends upon the character of the stone, upon whether it is broken by hand or in a crusher (probably also on the kind of crusher), and upon whether it is screened into different sizes, or the run of the crusher is taken.

Pure quartz weighs 165 lbs. per cu. ft., hence broken quartz having 40% voids weighs 165 × 60%, or 99 lbs. per cu. ft. Few gravels are entirely quartz, and many contain stone having a greater specific gravity like some traps, or a less specific gravity like some shales and sandstones.

TABLE XI.

Specific Gravity of Stone.

(Condensed from Merrill's "Stones for Building.")

Trap, Boston, Mass	2.78
" Duluth, Minn	2.8 to 3.0
" Jersey City, N. J	3.03
" Staten Island, N.Y	2.86
Gneiss, Madison Ave., N.Y	2.92
Granite, New London, Conn	2.66
" Greenwich, Conn	2.84
" Vinalhaven, Me	2.66
" Quincy, Mass	2.66
" Barre, Vt	2.65
Limestone, Joilet, Ill	2.56
" Quincy, Ill.	2.51 to 2.57
" (oolitic) Bedford, Ind	2.25 to 2.45
" Marquette, Mich.	2.34
" Glens Falls, N. Y.	2.70
" Lake Champlain, N. Y	2.75
Sandstone, Portland, Conn	2.64
" Haverstraw, N. Y.	2.13
" Medina, N. Y	2.41
" Potsdam, N. Y	2.60
" (grit) Berea, O	2.12

TABLE XII.

Specific Gravity of Common Minerals and Rocks.

Apatite	2.92—3.25
Basalt	3.01
Calcite, $CaCO_3$	2.5 —2.73
Cassiterite, SnO_2	6.4 —7.1
Cerrusite, $PbCo_3$	6.46—6.48
Chalcopyrite, $CuFeS_2$	4.1 —4.3
Coal, anthracite	1.3 —1.84
Coal, bituminous	1.2 —1.5
Diabase	2.6 —3.03
Diorite	2.92
Dolomite, $CaMg(CO_3)_2$	2.8 —2.9
Feldspar	2.44—2.78
Felsite	2.65
Galena, PbS	7.25—7.77
Garnet	3.15—4.31
Gneiss	2.62—2.92
Granite	2.55—2.86
Gypsum	2.3 —3.28
Halite (salt), NaCl	2.1 —2.56
Hematite, Fe_2O_3	4.5 —5.3
Hornblende	3.05—3.47
Limonite, $Fe_3O_4(OH)_6$	3.6 —4.0
Limestone	2.35—2.87
Magnetite, Fe_3O_4	4.9 —5.2
Marble	2.08—2.85
Mica	2.75—3.1
Mica Schist	2.5 —2.9
Olivine	3.33—3.5
Porphyry	2.5 —2.6
Pyrite, FeS_2	4.83—5.2
Quartz, SiO_2	2.5 —2 8
Quartzite	2.6 —2.7
Sandstone	2.0 —2.78
" Medina	2.4
" Ohio	2.2
" Slaty	1.82
Shale	2.4 —2.8
Slate	2.5 —2.8
Sphalerite, ZnS	3.9 —4.2
Stibnite, Sb_2S_3	4.5 —4.6
Syenite	2.27—2.65
Talc	2.56—2.8
Trap	2.6 —3.0

The weight of a cubic foot of loose gravel or stone is therefore no accurate index of the percentage of voids unless the specific gravity is known.

Tables XI. and XII. show specific gravities of different minerals and rocks, and weights of broken stone corresponding to different percentages of voids.

It is rare that a gravel has less than 30% or more than 45% voids. If the pebbles vary considerably in size, so that the small fit in between the large, the voids may be as low as 30%; but if the pebbles are tolerably uniform the voids will approach 45%.

Broken stone, being angular, does not compact so read-

TABLE XIII.

Specific Gravity.	Weight in Lbs. per cu. ft.	Weight in Lbs. per cu. yd.	Weight in Lbs. per cu. yd. when Voids are 30%	35%	40%	45%	50%
1.0	62.355	1,684	1,178	1,094	1,010	926	842
2.0	124.7	3.367	2,357	2,187	2,020	1,852	1,684
2.1	130.9	3,536	2.475	2,298	2,121	1,945	1,768
2.2	137.2	3,704	2,593	2,408	2,222	2,037	1,852
2.3	143.4	3,872	2,711	2,517	2,323	2,130	1,936
2.4	149.7	4,041	2,828	2,626	2,424	2,222	2,020
2.5	155.9	4,209	2,946	2,736	2,525	2,315	2,105
2.6	162.1	4,377	3,064	2,845	2,626	2,408	2,189
2.7	168.4	4,546	3,182	2,955	2,727	2,500	2,273
2.8	174.6	4,714	3,300	3,064	2,828	2,593	2,357
2.9	180.9	4,882	3,418	3,174	2,929	2,685	2,441
3.0	187.1	5.051	3,536	3,283	3.030	2,778	2,526
3.1	193.3	5,219	3,653	3,392	3,131	2,871	2,609
3.2	199.5	5,388	3,771	3,502	3,232	2,963	2,694
3.3	205.8	5,556	3,889	3,611	3,333	3,056	2,778
3.4	212.0	5,724	4,007	3,721	3,434	3,148	2,862
3.5	218.3	5,893	4,125	3,830	3,535	3,241	2,947

TABLE XIV.

Voids in Loose Broken Stone.

Authority.	% Voids.	Remarks.
Sabin	49.0	Limestone, crusher run after screening out ⅛-in. and under.
"	44.0	Limestone (1 part screenings mixed with 6 parts broken stone).
Wm. M. Black	46.5	Screened and washed, 2 ins. and under.
J. J. R. Croes	47.5	Gneiss, after screening out ¼-in. and under.
S. B. Newberry	47.0	Chiefly about egg size.
H. P. Boardman	39 to 42	Chicago limestone, crusher run.
"	48 to 52	" " screened into sizes.
Wm. H. Hall	48.0	Green River limestone, 2½ ins. and smaller, dust screened out.
Wm. H. Hall	50.0	Hudson River trap, 2½ ins. and smaller, dust screened out.
Wm. B. Fuller	47.6	New Jersey trap, crusher run, ⅛ to 2.1 in.
Geo. A. Kimball	49.5	Roxbury conglomerate, ½ to 2½ ins.
Myron S. Falk	48.0	Limestone, ½ to 3 ins.
W. H. Henby	43.0	" 2-in. size.
"	46.0	" 1½-in. size.
Feret	53.4	Stone, 1.6 to 2.4 ins.
"	51.7	" 0.8 to 1.6 in.
"	52.1	" 0.4 to 0.8 in.
A. W. Dow	45.3	Bluestone, 89% being 1½ to 2½ ins.
"	45.3	" 90% being ⅛ to 1½ in.
Taylor and Thompson	54.5	Trap, hard, 1 to 2½ ins.
"	54.5	" " ½ to 1 in.
"	45.0	" " 0 to 2½ ins.
"	51.2	" soft, ¾ to 2 ins.
G. W. Chandler	40.0	Canton, Ill.
Emile Low	39.0	Buffalo limestone, crusher run, dust in.
C. M. Saville	46.0	Crushed cobblestone, screened into sizes.

ily as gravel, and shows a higher percentage of voids when the fragments are uniform in size and shoveled loosely into a box; but the voids, even then, seldom exceed 52%.

The following records of actual tests will indicate the range of void percentages:

Prof. S. B. Newberry gives the voids in Sandusky Bay gravel, ¼ to ⅛-in. size, as being 42.4% voids; ¼ to 1/20-in. size, 35.9% voids.

Mr. William H. Hall gives the following tests on mixtures of Green River, Ky., blue limestone and Ohio River washed gravel:

Stone		Gravel	Voids in Mixture
100%	with	0%	48%
80	"	20	44
70	"	30	41
60	"	40	38½
50	"	50	36
0	"	100	35

The stone passed a 2½-in. screen and the dust was removed by a fine screen. The gravel passed a 1½-in. screen.

The voids in mixtures of Hudson River trap rock and clean gravel, of the sizes just given for the Kentucky materials, were as follows:

Trap		Gravel	Voids in Mixture
100%	with	0%	50%
60	"	40	38¼
50	"	50	36
0	"	100	35

Mr. H. von Schon gives tests on a gravel having 34.1% voids as follows:

Retained on	1-in ring	10.70%
"	⅜-in. ring	23.65
"	No. 4 sieve	8.70
"	No. 10 sieve	17.14
"	No. 20 sieve	21.76
"	No. 30 sieve	6.49
"	No. 40 sieve	5.96
Passed	No. 40 sieve	5.59
"	1½-in ring	100.00

Feret gives the following results of tests on mixtures of different sizes of pebbles, and mixtures of different sizes of stone (the stone and pebbles were not mixed together):

Passing a ring of....	2.4″	1.6″	0.8″	Voids in Round Pebbles	Voids in Broken Stone
Held by a ring.......	1.6″	0.8″	0.4″		
Parts	1	0	0	40.0%	53.4%
"	0	1	0	38.8	51.7
"	0	0	1	41.7	52.1
"	1	1	0	35.8	50.5
"	1	0	1	35.6	47.1
"	0	1	1	37.9	49.5
"	1	1	1	35.5	47.8
"	4	1	1	34.5	49.2
"	1	4	1	36.6	49.4
"	1	1	4	38.1	48.6
"	8	0	2	34.1	

Mr. A. W. Dow gives the following tests on mixtures of broken stone and gravel at Washington, D. C.:

Parts of Broken Bluestone: Granolithic (92% being $\frac{1}{10}''$ to $\frac{1}{3}''$)	Parts of Broken Bluestone: Coarse (89% being $1\frac{1}{2}''$ to $2\frac{1}{2}''$)	Parts of Broken Bluestone: Average (90% being $\frac{1}{3}''$ to $2''$)	Parts of Gravel: Average (90% being $\frac{1}{8}''$ to $1\frac{1}{2}''$)	Parts of Gravel: Small (90% being $\frac{1}{8}''$ to $\frac{3}{4}''$)	Voids. Per cent.
....	1	....	....	....	45.3
....	....	1	....	....	45.3
1	....	1	....	....	39.5
....	....	....	1	....	29.3
....	....	1	....	1	35.5
....	....	2	....	1	36.7

Taylor and Thompson give the following:

Ref. No.	Stone	Size	Voids in loose stone	Per cent. Compression by light ramming or shaking	Per cent. Voids after light ramming	Per cent. Compression by heavy ramming	Per cent. Voids after heavy ramming
1....	Hard trap	$2\frac{1}{2}''$ to $1''$	54.5	.....	.....	19.2	43.7
2....	"	$1''$ to $\frac{1}{2}''$	54.5	14.3	46.9	20.5	42.8
3....	"	$2\frac{1}{2}''$ to 0	45.0	14.5	35.7	20.8	30.6
4....	Soft trap	$2''$ to $\frac{3}{4}''$	51.2	11.9	44.6	17.8	40.6
5....	"	$\frac{3}{4}''$ to $\frac{3}{8}''$	51.2	14.3	43.1	23.9	35.9
6....	Gravel	$2\frac{1}{2}''$ to $\frac{1}{2}''$	36.5	12.5	27.4	11.5	28.2

The stone was thrown into a measuring box and measured, then rammed in 6-in. layers. The variation in the last column for Nos. 4 and 5 was due to the breaking of the trap under the rammer. No. 3 was "crusher run" containing 44.4% of No. 1, 33.3% of No. 2, and 22% of screenings from ½-in. down to dust. Nos. 1, 2 and 3 were crushed in a gyratory crusher; Nos. 4 and 5, in a jaw crusher.

Mr. George W. Rafter gives the voids in clean limestone,

broken (by hand?) to pass a 2½-in. ring, as 43% after being "slightly shaken," and 37½% after being rammed.

Mr. Desmond Fitzgerald states that broken stone dropped 12 ft. into a car measured 7% less in volume after the fall.

As stated in my "Rock Excavation," I have found that a wagon load of broken stone measures 10% less in volume after it has traveled a short distance, due to the shaking down. In buying broken stone by the cubic yard it is well to bear this fact in mind.

Percentage of Water Required in Mortar.—A good rule by which to determine the percentage of water by weight for any given mixture of mortar is as follows: Multiply the parts of sand by 8, add 24 to the product and divide the total by the sum of the parts of sand and cement.

Example: Required percentage of water for a mortar of 1 cement to 3 sand:

Solution.

$$\begin{array}{lcl} 1 \text{ cement} & = & 24\% \\ 3 \text{ sand} \times 8\% & = & 24\% \\ \hline 4 \text{ parts at } 12\% & = & 48\% \end{array}$$

Hence the water should be 12% of the combined weight of the cement and sand. For a 1:1 mortar, the rule gives 16% water. For 1:2 mortar, the rule gives 13⅓% water. For a 1:6 mortar, the rule gives 10.3% water. Incidentally, it may be added, the percentages of water obtained by this rule give a mortar that has the greatest adhesion to steel rods (see Falk's "Cements, Mortars and Concretes," page 61).

Cost of Sand.—The cost of sand may be estimated by adding together the cost of loading in the pit, the cost of hauling in wagons, the cost of freight and rehandling if necessary and the cost of washing. On page 271 are given data on the cost of shoveling sand into wagons. The cost of wagon hauling is given on page 83. Freight rates can always be secured, and it is usually safe to estimate the weight on a basis of 2,700 lbs. per cu. yd., provided the sand has not been rained upon after loading in the car. The cost of screening sand by hand is the cost of shoveling it up against an inclined screen; but if a large amount of gravel must be screened to get a small amount of sand, care must

be taken to make tests in the pit to ascertain how many cubic feet of gravel and sand must be shoveled to secure one cubic foot of sand. In some places sand must be dredged or pumped with a sand pump from the bottom of a river or lake. In other places sand must be made by crushing stone and running the small crushed product through rolls. At Coudersport, Pa., a small plant for making artificial sand from stone has been in operation for many years.

Stone was crushed and passed through rolls in order to make a sand for the mortar used in the Lanchensee Dam, Germany. A jaw crusher, driven by a 15-HP. engine, crushed 65 cu. yds. of stone (graywacke) per 10-hr. day. All pieces from 0.16 to 1.6 ins. diameter were passed through rolls. The rolls were 14½ ins. long and 34 ins. diameter, and made 22 revolutions per minute, requiring 12 to 15 HP. A pair of these rolls produced 20 cu. yds. of sand per 10-hr. day. The rolls had chilled bands which, when worn, were ground true with an emery wheel without removing the rolls.

Where a large amount of concrete is to be made, a contractor can seldom afford to guess at the source of his sand supply. I have known several instances where long hauls over poor roads have made the sand more expensive than the stone per cubic yard of concrete. Each job should be estimated in detail, using the data given elsewhere in this book.

A very common price for sand in cities is $1 per cu. yd., delivered at the work. Sand is often sold by the load, instead of by the cubic yard. It is wise to have a written agreement defining the size of a load.

Cost of Washing Sand With a Hose.—Where the quantity of sand to be washed is not very large, the simplest method is to use water from a hose. Build a tank 8 ft. wide and 15 ft. long, the bottom having a slope of about 8 ins. in the 15 ft. The sides should be about 8 ins. high at the lower end, rising gradually to 3 ft., the height of the upper end. The lower end of this tank should be closed with a board gate about 6 ins. high, sliding in guides so that it can be removed. Dump about 3 cu. yds. of the dirty sand at the upper end of the platform and play a stream of water upon it from a ¾-in. nozzle, the man standing on the out-

side of the lower end of the platform. The water and sand flow down the platform and the dirt passes off with the overflow water over the gate. In about an hour the batch of sand will be washed. By building a pair of platforms the washing can proceed continuously; and one man can wash 30 cu. yds. a day, at a cost of 5 cts. per cu. yd. for his labor. To this must be added the cost of shoveling up the sand again, say, 10 cts. per cu. yd., and any extra hauling due to the location of the washer. If the water is pumped, about 10 cts. more per cu. yd. will be spent for coal and wages, making a total of 25 cts. per cu. yd.

Washing With Sand Ejectors.—Where very large quantities of sand are to be washed more expensive apparatus than above described may be used. In Engineering News, Feb. 13 and Sept. 11, 1902, will be found detail drawings of what are termed "sand ejectors," consisting of a row of conical hoppers now used extensively for washing filter sand. From the bottom of each hopper the sand and water are forced to the top of the next hopper by a stream of water passing through an ejector. The dirty water overflows at the top of each hopper, and finally clean sand is discharged into receiving bins or buckets. One man can readily attend to feeding the sand into the first hopper and another man will handle the discharge. It requires about 3,000 gallons of water per cu. yd. of sand washed, so that with an output of 36 cu. yds. of sand in 10 hrs., the amount of water to be pumped is 108,000 gallons. A gasoline pump may be used.

Cost of Washing Sand in a Tank Washer.—Mr. W. H. Roper gives the following data on the cost of washing sand for U. S. Lock No. 3, at Springdale, Pa. The sand dredged from the river contained much fine coal and silt which was removed by the washer, which consisted of a circular tank, 9 ft. diam. × 7 ft. high, provided with a sloping false bottom perforated with 1-in. holes, through which water was forced. A 7½ × 5 × 6-in. pump with a 3-in. discharge pipe was used to force the water into the tank. The paddles for keeping the sand in suspension were rotated by a 7-HP. engine. A charge of 14 cu. yds. of sand was washed in from 1 to 2 hrs., at a cost of 7 cts. per cu. yd. This device was designed by Capt. W. R. Graham, who is

said to have applied for a patent. It is doubtful whether any patentable combination exists in the device.

Mr. F. H. Stephenson gives the following data relating to a sand washer designed by Mr. Allen Hazen, which consisted of a wooden box 10 ft. long, 2½ ft. wide and 2½ ft. deep; a 6-in. pipe, provided with a gate, or valve, enters at one end, and connects with three 3-in. pipes capped at the ends. In the bottoms of these 3-in. pipes are ½-in. holes, spaced 6 ins. apart, through which water discharges under pressure into the box. Sand is shoveled into the box at one end, and the upward currents of water raise the fine and dirty particles until they escape through the waste troughs. When the box becomes filled with sand a sliding door is raised at the end, and the clean sand flows out through a 3-in. hole in the box. The operation is continuous, so long as sand is fed into the washer. By manipulating the door the sand can be made to flow out with a very small percentage of water. Sand containing 7% of dirt was thus washed so that it contained only 0.6% dirt. In 10 hours the washer handled 200 cu. yds. of sand.

If sand is handled to and from the washers by shovels, the cost of shoveling is the largest item of expense, and this can be easily estimated. If the sand is dumped into bins which feed into the washer by gravity, and is finally delivered by gravity to buckets or cars, the cost of washing is mainly the cost of pumping, plus the interest and depreciation of plant. The amount of water required per cubic yard has been given above, so that a close estimate of cost can readily be made for any given condition.

Cost of Making Concrete by Hand.—The cost of making concrete by hand may be divided into the following items:

(1) Loading the barrows, buckets, carts or cars used to transport the materials (stone, sand and cement) to the mixing board.

(2) Transporting and dumping the materials.

(3) Mixing the materials by turning with shovels or hoes.

(4) Loading the concrete with shovels into barrows, buckets, carts or cars.

(5) Transporting the concrete to place.

(6) Dumping and spreading.

(7) Ramming.
(8) Forms, runways, cement house, bins, etc.
(9) Finishing the surface of the concrete.
(10) Superintendence and general expenses.

Unloading the Materials From Cars.—The stone and sand will ordinarily be delivered by wagons or cars and dumped into stock piles as near the proposed work as possible, without being in the way after construction begins. The contractor should use forethought not only in planning the location of his stock piles, but also in providing a large enough storage capacity to tide over irregularities in the delivery of materials, especially where materials come by rail from a distance. It is usually a short-sighted policy to attempt to unload direct from railway cars onto the mixing board, without providing a stock pile; for the foreman will be spending most of his time trying to get the railroad to deliver materials promptly. By all means provide stock piles, unless there is some good reason to the contrary.

Sand can be dumped directly on the ground, but broken stone (unless it is very small, ¾-in. or less in size) should always be dumped upon a plank floor, well made. Such a floor should consist of 2-in. plank laid on 4 × 6-in. stringers firmly bedded in the ground and spaced about 3 ft. apart. Never lay a lot of loose plank directly upon the ground, without stringers, for they are sure to settle unevenly under the load, and thus make it difficult to shovel up the stone. The object of the plank is to provide an even surface along which a square pointed shovel can be pushed in loading barrows, carts, etc. I find that a man can load 18 or 20 cu. yds. of broken stone into wheelbarrows in 10 hrs., if he is shoveling off a well-laid plank platform, but he will not average more than 12 or 14 cu. yds. a day shoveled from a pile without a plank flooring. The reason is that a shovel can be shoved with difficulty into a mass of broken stone (2-in. size), but can readily be shoved along a plank floor. Incidentally I may add that broken stone delivered in hopper-bottom cars can be shoveled with difficulty as compared with shoveling in flat-bottom cars; the ratio being about 14 cu. yds. per man per day from hopper-bottom cars as compared with 20 cu. yds. from flat cars. On the other hand, the hopper-bottom coal car should always be chosen where

it can be dumped through a trestle. If the amount of work to be done will justify the expense a trestle may be built. Often, however, there is a railroad embankment which can be dug away for a short distance and stringers placed to support the track. Then the cars can be dumped into the hole thus made, and the material shoveled out and down the slope.

I have seen many foremen for railway companies wasting hundreds of dollars by shoveling the materials from freight cars out upon the earth—often upon the side of an embankment where shoveling is very difficult. In many cases it would have paid well to have unloaded the cars by the aid of a stiff-leg derrick and iron buckets or skips loaded by the shovelers in the cars; these skips being dumped upon a well made platform. In other cases chutes lined with sheet iron would have served to deliver the stone upon a plank flooring at the foot of the embankment, just as coal is delivered into a cellar. Damp sand will not slide down a chute on a slope of 1½ to 1, but coarse broken stone, if given a start when cast, with the shovel, will slide on an iron-shod slope of 3 or 4 to 1.

If the material is delivered in wagons it seldom is necessary to have large stock piles provided the wagons come direct from the sand pit and the quarry.

Cost of Loading the Materials.—A man who is a willing worker can readily load 20 cu. yds. of sand into a barrow or cart in 10 hrs., but under poor foremen, or when laborers are scarce, it is not safe to count upon more than 15 cu. yds. a day, or, say, 10 cts. per cu. yd. for loading. Practically the same figures hold true of broken stone shoveled off a good plank floor; but, if the stone is shoveled off the ground, estimate 15 cu. yds. a day under good management, or 12 cu. yds. a day under poor management. Since in a cubic yard of concrete there are ordinarily about 1 cu. yd. of broken stone and about 0.4 cu. yd. of sand, the cost of loading the materials into wheelbarrows and carts is as follows, wages being 15 cts. per hour:

1 cu. yd. stone loaded for	11 cts.
0.4 " " sand " "	4 "
1 cu. yd. concrete loaded for	15 cts.

The cement can be loaded with more ease than the other materials, whether it is in barrels or in bags, and the cost of loading it into barrows or carts will be not over 2 cts. per cu. yd. of concrete, thus making a total of 17 cts. per cu. yd. for loading the concrete materials into barrows or carts.

Cost of Transporting the Materials.—The most common way of transporting the materials from stock piles to the mixing board is in wheelbarrows over plank runways. A wheelbarrow is usually loaded with 2 sacks of Portland cement (200 lbs.), or with 2 cu. ft. of stone or of sand, if a steep rise must be made to reach the mixing platform; but, if the run is level, 300 lbs. of cement, or 3 cu. ft. of sand or stone is a common wheelbarrow load. A man wheeling a barrow travels at the rate of about 200 ft. per minute, going and coming, and loses ¾ minute each trip dumping the load, fixing run planks, etc. An active man will do 20 or 25% more work than this, while a very lazy man may do 20% less. With wages at 15 cts. per hour, the cost of wheeling the materials for 1 cu. yd. of concrete may be obtained by the following rule:

To a fixed cost of 4 cts. (for lost time) add 1 ct. for every 20 ft. of distance from stock pile to mixing board if there is a steep rise in the runway, but if the runway is level add 1 ct. for every 30 ft. distance of haul. Since loading the barrows costs 17 cts. per cu. yd., the total fixed cost is 4 + 17 cts. or 21 cts. per cu. yd., to which is added 1 ct. for every 20 or 30 ft. of haul, according to the character of the runway.

I have frequently seen small stock piles located as close as possible to mixing boards, so that wheelbarrows were not used, the materials being carried in shovels direct to the mixing boards. On work of any considerable size this is a very foolish plan, as we can readily see. It takes from 100 to 150 shovelfuls of stone to make 1 cu. yd. It therefore costs at the rate of 50 cts. per cu. yd. to carry it 100 ft. and return empty handed, for in walking short distances the men travel very slowly—about 150 ft. per minute. From this it appears that it costs more to walk even half a dozen paces with stone carried in shovels than to wheel it in barrows. Of course, by using large coal scoops the cost of carrying material in shovels could be reduced to one-half or one-third the cost with ordinary shovels; but scoops are never used in mixing concrete.

Another mistake that is very commonly made by foremen is to provide no plank runways from the stock pile to the mixing board, but instead to run the wheelbarrows over the ground. This is bad enough even in dry weather over a very hard packed earth path, but after a rain or on a soft pathway it means a great loss of efficiency. Had I not seen this error committed repeatedly, I should not mention it, for it would seem that no foreman could be so short-sighted as not to provide a few planks for runways.

Where the runway must rise to the mixing board, give it a slope or grade seldom steeper than 1 in 8, and if possible flatter. Make a runway on a trestle at least 18 ins. wide, so that men will be in no danger of falling. See to it, also, that the planks are so well supported that they do not spring down when walked over, for a springy plank makes hard wheeling. If the planks are so long between the "horses" or "bents" used to support them, that they spring badly, it is usually a simple matter to nail a cleat across the underside of the planks and stand an upright strut underneath to support and stiffen the plank.

Materials may be hauled in one-horse dump-carts for all distances more than 50 ft. (from stock pile to mixing board) at a cost less than for wheelbarrow hauling. A cart should be loaded in 4 mins. and dumped in about 1 min., making 5 mins. lost time each round trip. It should travel at a speed of not less than 200 ft. per min., although it is not unusual to see variations of 15 or 20%, one way or another, from this average, depending upon the management of the work. A one-horse cart will readily carry enough stone and sand to make ½ cu. yd. of concrete, if the roads are fairly hard and level; and a horse can pull this load up a 10% (rise of 1 ft. in 10 ft.) planked roadway provided with cleats to give a foothold. If a horse, cart and driver can be hired for 30 cts. per hour, the cost of hauling the materials for 1 cu. yd. of concrete is given by the following rule:

To a fixed cost of 5 cts. (for lost time at both ends of haul) add 1 ct. for every 100 ft. of distance from stock pile to mixing board. Where carts are used it is possible to locate the stock piles several hundred feet from the mixing boards without adding materially to the cost of the concrete. It is well, however, to have the stock piles in sight of the foreman at the mixing board, so as to insure promptness of delivery.

Cost of Mixing the Materials.—This element of cost depends upon the number of times that the materials are turned over with shovels. I have seen street paving work where the inspection was so lax that the contractor was required to turn over the mass of sand, cement and stone only three times before shoveling it into place. On the other hand, the contractor is rarely required to turn over the cement and sand more than three times dry and three times wet to make the mortar, and then turn over the mortar and stone three times. A willing workman, under a good foreman, will turn over mortar at the rate of 30 cu. yds. in 10 hrs., lifting each shovelful and casting it into a pile. This means a cost of 5 cts. per cu. yd. of mortar for each turn; but as there is seldom more than 0.4 cu. yd. of mortar per cu. yd. of concrete, we have a cost of 2 cts. per cu. yd. of concrete for each turn that is given to the mortar. So if the mortar is given 6 turns before adding the stone, we have 2 cts. × 6 which is 12 cts. per cu. yd. of concrete for mixing the mortar. Then if the mortar and stone are turned three times we have 5 cts. × 3, or 15 cts. more for mixing, thus making a total of 27 cts. per cu. yd. for mixing the concrete, wages being 15 cts. per hr.

I recall seeing one specification that called for 6 turns of the mortar dry and 3 turns wet. Under such a specification the cost of mixing the mortar would be 50% more than I have assumed in the example just given. Specifications for hand mixing should always state the number of turns that will be required, but frequently they do not, thus leaving the contractor to guess at the probable requirements of the inspector. In such a case it is a good plan to use hoes instead of shovels for mixing the mortar, because in this way a good mortar can be mixed with much greater rapidity than when an inspector insists on 6 to 9 turns with shovels, as frequently happens when specifications are ambiguous.

As above stated, it often happens that on city pavement work, two turns of the mortar, followed by two turns of the mortar and stone, are considered sufficient. In such a case the cost of mixing the mortar is 2 cts. × 2, or 4 cts. per cu. yd. of concrete; to which is added 5 cts. × 2, or 10 cts., for mixing the mortar and stone, making in all 14 cts. per cu. yd. of concrete. When concrete is mixed very wet, or sloppy, this amount of mixing appears to give good results.

Where a given number of turns of concrete is specified, disputes often occur between inspectors and foremen as to whether shoveling into wheelbarrows constitutes a "turn" or not, and whether any subsequent shoveling in getting the concrete to its final resting place constitutes a "turn." It seems but fair to count each handling with the shovel as a turn, no matter when or where it occurs, but inspectors will not always look upon it in that light.

The foregoing costs of mixing apply to work done by diligent men; but easy-going men will make the cost 25 to 50% greater. I have seen this latter class of men most frequently on day labor work for cities, railways and other companies and corporations whose foremen have little or no incentive to secure a fair day's work from the men.

Cost of Loading and Hauling Concrete.—The cost of loading concrete, after it is mixed, is less than the cost of loading the materials separately before mixing, because while the weight is greater (due to the added water), the bulk or volume of the concrete is much less than the volume of the ingredients before mixing. Moreover a smooth mixing board, and the presence of the foreman, secures more rapid work. In shoveling any material a large part of the work consists in forcing the shovel into, or under, the mass to be lifted. With wages at 15 cts. per hour, the cost of loading concrete into barrows or buckets should not exceed 12 cts. per cu. yd. The cost of wheeling it after loading is practically the same as for wheeling the dry ingredients, as given by the rule on page 272. The cost per cubic yard of loading and wheeling is therefore given by this rule: To a fixed cost of 16 cts. (for loading and lost time) add 1 ct. for every 30 ft. of level haul.

If the concrete must be elevated, a gallows frame, or a mast with a pulley block at the top, a team of horses and a rope for hoisting the skip load of concrete, can often be used to advantage. An example of the cost of filling steel cylinders by this method is given on page 336.

Another method, well worthy of more frequent use, consists in wheeling the barrows of concrete to a gallows frame where they are raised by a horse, and then wheeled to place, as described on page 327.

In building railway abutments, culverts, and the like, it is often desirable to locate the mixing board on high ground,

perhaps at some little distance from the forms. If this can be done, the use of derricks may be avoided as above suggested or by building a light pole trestle from the mixing board to the forms. The concrete can then be wheeled in barrows and dumped into the forms. If the mixing board can be located on ground as high as the top of the concrete structure is to be, obviously a trestle will enable the men to wheel on a level runway. Such a trestle can be built very cheaply, especially where second-hand lumber, or lumber that can be used subsequently for forms is available. A pole trestle whose bents are made entirely of round sticks cut from the forest is a very cheap structure, if a foreman knows how to throw it together and up-end the bents after they are made. I have put up such trestles for 25 cts. per lineal foot of trestle, including all labor of cutting the round timber, erecting it, and placing a plank flooring 4 ft wide on top. The stringers and flooring plank were used later for forms, and their cost is not included. A trestle 100 ft. long can thus be built at less cost than hauling, erecting and taking down a derrick; and once the trestle is up it saves the cost of operating a derrick.

Concrete made with Portland cement (but not with natural cement) can be hauled long distances in a cart or wagon before it begins to harden. This fact should be taken advantage of by contractors far oftener than it is. I am inclined to think that the extensive use of natural cement, which sets too quickly to admit of hauling far, has blinded contractors to the possibilities of saving money by hauling Portland cement concrete long distances. Since a cart is readily hauled at a speed of 200 ft. a minute, where there are no long steep hills, it is evident that in 6½ minutes a cart can travel a quarter of a mile; in 13 mins., half a mile; and in 26 minutes, a mile. Now, Portland cement does not begin to set for 30 minutes; hence it may be hauled a mile after mixing it. The cost of hauling concrete with one-horse dump-carts is practically the same as the cost of hauling its dry ingredients, as given on page 272.

Cost of Dumping, Spreading and Ramming.—The cost of dumping wheelbarrows and carts is included in the rules of cost already given, excepting that in some cases it is necessary to add the wages of a man at the dump who assists the cart drivers or the barrow men. Thus in dump-

ing concrete from barrows into a deep trench or pit, it is usually advisable to dump into a galvanized iron hopper provided with an iron pipe chute. One man can readily dump all the barrows that can be filled from a concrete mixer in a day, say 150 cu. yds. At this rate of output the cost of dumping would be only 1 ct. per cu. yd., but if one man were required to dump the output of a small gang of men, say 25 cu. yds., the cost of dumping would be 6 cts. per cu. yd.

Concrete dumped through a chute requires very little work to spread it in 6-in. layers; and, in fact, concrete that can be dumped from wheelbarrows, which do not all dump in one place, can be spread very cheaply; for not more than half the pile dumped from the barrow needs to be moved, and then moved merely by pushing with a shovel. Since the spreader also rams the concrete, it is difficult to separate these two items. As nearly as I have been able to estimate this item of spreading "dry" concrete dumped from wheelbarrows in street paving work, the cost is 5 cts. per cu. yd. If, on the other hand, nearly all the concrete must be handled by the spreaders, as in spreading concrete dumped from carts, the cost is fully double, or 10 cts. per cu. yd. And if the spreader has to walk even 3 or 4 paces to place the concrete after shoveling it up, the cost of spreading will be 15 cts. per cu. yd. For this reason it is apparent that carts are not as economical as wheelbarrows for hauling concrete up to about 200 ft., due to the added cost of spreading material delivered by carts.

The preceding discussion of spreading is based upon the assumption that the concrete is not so wet that it will run. Obviously where concrete is made of small stones and contains an excess of water, it will run so readily as to require little or no spreading.

The cost of ramming concrete depends almost entirely upon its dryness and upon the number of cubic yards delivered to the rammers. Concrete that is mixed with very little water requires long and hard ramming to flush the water to the surface. The yardage delivered to the rammers is another factor, because if only a few men are engaged in mixing they will not be able to deliver enough concrete to keep the rammers properly busy, yet the rammers by slow though continuous pounding may be keeping

up an appearance of working. Then, again, I have noticed that the slower the concrete is delivered the more particular the average inspector becomes. Concrete made "sloppy" requires no ramming at all, and very little spading.

I have had men do very thorough ramming of moderately dry concrete for 15 cts. per cu. yd., where the rammers had no spreading to do, the material being delivered in shovels. It is rare indeed that spreading and ramming can be made to cost more than 40 cts. per cu. yd., under the most foolish inspection, yet one instance is recorded on page 336 of even higher cost.

If engineers specify a dry concrete and "thorough ramming" they would do well also to specify what the word "thorough" is to mean, using language that can be expressed in cents per cubic yard. It is a common thing, for example, to see a sewer trench specification in which one tamper is required for each two men shoveling the back-fill into the trench; and some such specific requirement should be made in a concrete specification if close estimates from reliable contractors are desired. Surely no engineer will claim that this is too unimportant a matter for consideration when it is known that ramming can easily be made to cost as high as 40 cts. per cu. yd., depending largely upon the whim of the inspector.

The Cost of Superintendence.—This item is obviously dependent upon the yardage of concrete handled under one foreman and the daily wages of the foreman. If a foreman receives $3 a day and is bossing a job where only 12 cu. yds. are placed daily, we have a cost of 25 cts. per cu. yd. for superintendence. If the same foreman is handling a gang of 20 men whose output is 50 cu. yds., the superintendence item is only 6 cts. per cu. yd. If the same foreman is handling a concrete-mixing plant having a daily output of 150 cu. yds., the cost of superintendence is but 2 cts. per cu. yd. I have given these elementary examples simply because figures are more impressive than generalities, and because it is so common a sight to see money wasted by running too small a gang of men under one foreman.

Of all classes of contract work, none is more readily estimated day by day than concrete work, not cnly because it is usually built in regular shapes whose volumes are easily ascertained at the end of each day, but because a

record of the bags, or barrels, or batches gives a ready method of computing the output of each gang. For this reason small gangs of concrete workers need no foreman at all, provided one of the workers is given command and required to keep tally of the batches. If the efficiency of a gang of 6 men were to fall off, say, 15%, by virtue of having no regular non-working foreman in charge, the loss would be only $1.35 a day—a loss that would be more than counterbalanced by the saving of a foreman's wages. Indeed, the efficiency of a gang of 6 men would have to fall off 25%, or more, before it would pay to put a foreman in charge. I know by experience that in many cases the efficiency will not fall off at all, provided the gang knows that its daily progress is being recorded, and that prompt discharge will follow laziness. Indeed, I have more than once had the efficiency increased by leaving a small gang to themselves in command of one of the workers who was required to punch a hole in a card for every batch.

To reduce the cost of superintendence there is no surer method than to work two gangs of 18 to 20 men, side by side, each gang under a separate foreman who is striving to make a better showing than his competitor. This is done with marked advantage in street paving, and could be done elsewhere oftener than it is.

In addition to the cost of a foreman in direct charge of the laborers, there is always a percentage of the cost of general superintendence and office expenses to be added. In some cases a general superintendent is put in charge of one or two foremen; and, if he is a high-salaried man, the cost of superintendence becomes a very appreciable item. One instance of this is given on page 328.

Summary of Costs.—Having thus analyzed the costs of making and placing concrete, we can understand why it is that printed records of costs vary so greatly. Moreover, we are enabled to estimate the labor cost with far more accuracy than we can guess it; for by studying the requirements of the specifications, and the local conditions governing the placing of stock piles, mixing boards, etc., we can estimate each item with considerable accuracy. My purpose, however, has not been solely to show how to predict the labor cost, but also to indicate to contractors and their foremen some of the many possibilities of reducing the cost of

work once the contract has been secured. I have found that an analysis of costs, such as above given, is the most effective way of discovering unnecessary "leaks," and of opening one's eyes to the possibilities of effecting economies in any given case.

To indicate the method of summarizing the costs of making concrete by hand, let us assume that the concrete is to be put into a deep foundation requiring wheeling a distance of 30 ft.; that the stock piles are on plank 60 ft. distant from the mixing board; that the specifications call for 6 turns of gravel concrete thoroughly rammed in 6-in. layers; and that a good sized gang of, say, 16 men (at $1.50 a day each) is to work under a foreman receiving $2.70 a day. We then have the following summary by applying the rules already given:

	Per cu. yd. concrete.
Loading sand, stone and cement	$ .17
Wheeling 60 ft. in barrows (4 + 2 cts.)	.06
Mixing concrete, 6 turns at 5 cts	.30
Loading concrete into barrows	.12
Wheeling 30 ft. (4 + 1 ct.)	.05
Dumping barrows (1 man helping barrowman)	.05
Spreading and heavy ramming	.15
Total cost of labor	$ .90
Foreman, at $2.70 a day	.10
Grand total	$1.00

To estimate the daily output of this gang of 16 laborers proceed thus: Divide the daily wages of all the 16 men, expressed in cents, by the labor cost of the concrete in cents, the quotient will be the cubic yards output of the gang. Thus, 2,400 ÷ 90 is 27 cu. yds., in this case.

In street paving work where no man is needed to help dump the wheelbarrows, and where it is usually possible to shovel concrete direct from the mixing board into place, and where half as much ramming as above assumed is usually satisfactory, we see that the last four labor items instead of amounting to 12 + 5 + 5 + 15, or 37 cts., amount only to one-half of the last item, ½ of 15 cts., or 7½ cts. This makes the total labor cost only 60 cts. instead of 90 cts. If we divide

2,400 cts. (the total day's wages of 16 men) by 60 cts. (the labor cost per cu. yd.), we have 40 which is the cubic yards output of the 16 men. This greater output of the 16 men reduces the cost of superintendence to 7 cts. per cu. yd.

Cost of Mixing Concrete With Machines.—Care must be taken not to confuse the cost of mixing concrete with the cost of delivering materials to the mixer and conveying the concrete away from the mixer. A study of the various costs given on subsequent pages will show that the cost of mixing alone is only a small part of the total cost of making concrete.

If all the materials are delivered to the machine in wheelbarrows, and if the concrete is conveyed away in wheelbarrows, the cost of making concrete, even with machine mixers, is high. On the other hand, where the materials are fed from bins by gravity into the mixer, and where the concrete is hauled away in cars, the cost of making the concrete may be very low.

There are three types of mixers: (1) Batch mixers; (2) continuous mixers; (3) gravity mixers. The cube mixers, double-cone mixers of the Smith make, and the drum mixers of the Ransome make, are all batch mixers in which a charge of materials is rotated for 10 or 15 turns and then discharged all at once. The continuous mixers have paddles or plows that stir up the materials as fast as they are delivered, a continuous stream of concrete being discharged. In the gravity mixers the falling materials strike baffle plates which perform the mixing.

Batch mixers are commonly made in three sizes, ½-yd., ¾-yd. and 1-yd. It is generally considered sufficient to give the mixer 10 to 15 turns, occupying 1 to 1½ minutes, after charging it with a batch; but as some time is consumed in charging and discharging, etc., it is safe to count on only one batch every 3 mins., or 200 batches in 10 hrs. If each batch is ½-yd., the daily output is 100 cu. yds.; if the batch is 1 yd., the daily output is 200 cu. yds.

Where the work is well organized, and no delays occur in delivering the materials to the mixer, a batch every 2 mins., or 300 batches in 10 hrs., will be averaged; and there are a few records of 1 batch every 1½ mins.

Not more than 12 HP. are required to run a ¾-yd. mixer. Where materials are delivered from bins or skips 2 men will charge a ¾-yd. mixer and 1 man will attend to dumping it, and a gasoline engine consuming 10 gals. of gasoline per 10-hr. day at 12½ cts. per gal., will represent the full cost of labor and fuel for mixing 200 cu. yds. If the 2 men are paid $1.50 each, and 1 man at $1.75, the cost of labor and fuel is only $6.00, or 3 cts. per cu. yd. It is not in the *mixing*, therefore, that the money is consumed, but in conveying materials to and from the mixer, in ramming the concrete, in installing the plant for mixing and conveying, and in interest and depreciation charges.

The following table gives sizes and capacities of the Ransome concrete mixer:

No. of Mixer.	(1)	(2)	(3)	(4)
Size of batch, cement, cu. ft.	1	2	3	4
" sand, "	3	6	9	12
" stone, "	6	12	18	24
Capacity per hour, cu. yds...	10	20	30	40
Horse power, engine.........	5 x 5	7 x 7	8 x 8	9 x 9
" rated..........	5 h.p.	10 h.p.	14 h.p.	20 h.p.
" boiler..........	30 x 60	36 x 72	42 x 84	42 x 108
" rated..........	7 h.p.	12 h.p.	20 h.p.	27 h.p.
Speed of drum, rev. per min.	16	15	14½	14
Speed of driving shaft, rev. per min....................	116	122	94	99
Measurements of drum......	54 diam. x 36	60 diam. x 42	63 diam. x 48	63 diam. x 54
Weights of mixer on skids..	2,700	2,800	4,800	5,000
Weights of mixer and engine on skids..............	3,800	4,600	7,500	9,200
Weights of mixer, engine and boiler on skids........	6,000	7,100	11,500	14,100

The Municipal Engineering and Contracting Co., of Chicago, gives the following data relative to the horse-power required for the different sizes of their cube mixer:

Number of Mixer.	Horse Power. Steam.	Horse Power. Gasoline.	Concrete in Place, cu. yds. per batch.
1	28	30	2
2	12	16	1
2½	9	12	⅔
3	6	9	½
4	5	6	⅓
5	3	4	$\frac{1}{5}$
6	1	1	$\frac{1}{12}$

The following data as to the weights of this mixer will be useful:

	Net, lbs.	Crated for Export, lbs.
½ yd. on Skids, with pulley or gear ..	3,600	6,300
½ " Wheels, with pulley or gear	4,550	7,970
½ " Skids, with engine mounted	4,350	7,800
½ " Wheels, with engine mounted	5,300	8,325
½ " Skids, engine and boiler mounted	6,250	10,937
½ " Wheels, engine and boiler mounted	7,200	12,600
1 " Skids, with pulley or gear ..	6,000	10,500
1 " Wheels, with pulley or gear..	7,425	13,000
1 " Skids, with engine mounted	7,250	12,737
1 " Wheels, with engine mounted	8,675	15,200
1 " Skids, engine and boiler mounted	10,600	18,550
1 " Wheels, engine and boiler mounted	12,000	21,000

Cost of Forms.—It is common practice to record the cost of forms or molds in cents per cubic yard of concrete, giving separately the cost of lumber and labor. This should be done, but the analysis of the cost of forms should always be carried a step farther. The records should be so kept as to show the first cost per M (i. e., 1,000 ft. B. M.) of lumber, the number of times the lumber is used, the labor cost of erecting, and the labor cost of taking down the forms each time—all expressed in M ft. B. M. Thus only is it possible to compare the cost of forms on different kinds of concrete work, and thus only can accurate predictions be made of

the cost of forms for concrete work having dimensions differing from work previously done. It is well also to make record of the number of square feet of exposed concrete surface to which the forms were applied. There are three ways, therefore, of recording the cost of forms: (1) In cents per cubic yard of concrete; (2) in cents per square foot of concrete face to which forms are applied; and (3) in dollars per M ft. B. M. of lumber used—in all three cases keeping the cost of materials and labor separate. Furthermore, it is well to make a sketch of the construction of the forms, and attach the sketch to the record of cost.

I find few engineers who are able to estimate closely the cost of forms for any class of concrete work that is new to them. This is due mainly to the practice of recording the costs only in terms of the cubic yard as the unit.

In estimating the probable cost of forms I find the following method most reliable: First, after ascertaining the time limit within which the work must be completed, determine the number of cubic yards of concrete that must be laid each day, after allowing liberally for delays. Knowing the number of cubic yards, estimate the number of thousand feet board measure of forms required to encase the concrete to be placed in a day. This will give the *minimum* amount of lumber required, for it is never permissible to move the forms until the concrete has hardened over night. This brings us to a very important question in economics. Thousands of words have been written on the advantages and disadvantages of using "wet" or "dry" concrete, but I have never seen mention of one of the most forceful objections to the use of concrete mixed so wet that it is sloppy. I refer to the slowness with which such concrete hardens. Obviously, the more slowly it hardens, the longer must the forms be left in place; and the longer the forms are left in place the more lumber will be required; the more the lumber, the greater the cost of forms per cubic yard of concrete.

A concrete mixed "dry," and rammed, will harden over night, so that in retaining wall construction it is safe to remove the forms the next morning; but, where the concrete has been mixed "sloppy," I have seen whole sections

of wall fall out upon the removal of forms twelve hours after placing the concrete. In cold weather the setting is further delayed, and in very cold weather it may cease entirely unless proper precautions are taken. Specifications relating to sloppy concrete usually provide that wall forms shall not be moved within 48 hours after placing the concrete; but in hot weather it is often safe to remove the forms in 24 hours or less.

Forms for concrete arches or beams must obviously be left in place longer than in wall work, because of the tendency to fail by rupture across the arch or beam. Forms for small circular arches, like sewers, may be removed in 18 to 24 hours if dry concrete is used; but in 24 to 48 hours if wet concrete is used. Forms for large arch culverts and arch bridges are seldom taken down in less than 14 days, and it is often specified that they must not be struck for 28 days after placing the last of the concrete. This last requirement is probably necessary where the backfilling over the arch is put on at once; but, except in the case of arches of great span, there appears to be no sufficient reason for keeping the centers so long under the arch, provided they can be used elsewhere. Indeed, I am inclined to think that a week's time is ample for arches having a span of 40 ft. or less, provided no filling is placed on the arch. In fact, a study of the compressive strength tests given in Falk's "Cements, Mortars and Concretes," pages 128, 131, etc., shows that the difference of compressive strength between 7-day and 28-day Portland cement mortar and concrete is often less than 25%, and averages about 50%; and that in any case concrete a week old is amply strong enough to hold its own weight in an arch of moderate size. Progressive settlement of the abutments might in some cases be given as a reason for leaving centers a long time in place, but abutments founded on rock or on piles do not show progressive settlement after the striking of centers, unless the subsequent jarring of trains causes the piles to go down.

Forms supporting concrete-steel floors and beams are usually left in a place at least a week.

The consideration of the time element in the use of forms

is essential in making an accurate forecast of the quantity of lumber that will be required in any given case. A few additional suggestions will not, therefore, be out of place.

Often the uprights or studs used to hold the sheeting plank are also used as legs for a trestle to support a track or runway over which the concrete is transported. In such a case the amount of timber in the forms is considerably

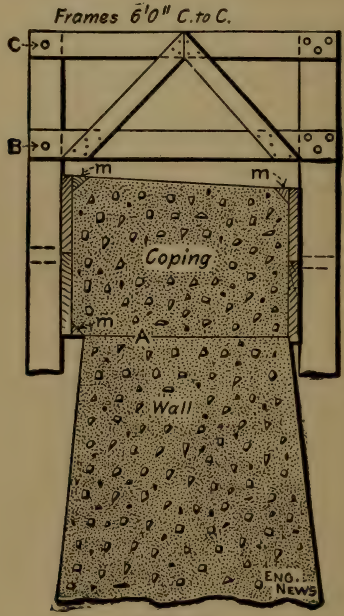


FIG. 13.

more than would be indicated by considering merely the length of time that the forms must stand before removal; for, so long as the uprights stand, it is impossible to remove the sheeting plank where ordinary kinds of forms are used. I have seen many instances of unnecessary expenditure of money for forms due to neglect to consider this fact. Bear in mind, therefore, that it may be cheaper to provide a movable derrick, or to use a cableway for de-

livering the concrete, rather than to use the uprights of the forms as posts for a trestle.

I have found it cheaper, as a rule, to build the coping of retaining walls after finishing the wall itself. One of the reasons for this is that a projecting coping is apt to fall, due to its own weight, if the forms are not left in place longer than it is necessary to leave the forms for the wall below the coping. In an editorial article in Engineering News, July 9, 1903, p. 37, I described the simple coping forms illustrated in Fig. 13. By providing frames with bolts B and C that can be taken out, the forms can be knocked down and used again and again. In building a 12-ft. section of coping, the frames may be supported on blocking or on the end of the last section of coping.

This leads us to the subject of building forms in panels that can be shifted from place to place without tearing the forms to pieces and building them up again. When panels can be used, it is evident that the cost of labor and lumber for forms may be reduced to a few cents per cubic yard of concrete. Examples of low cost of sewer work where the forms are thus shifted in sections will be found on subsequent pages. Even high retaining walls may thus be built with movable forms, as illustrated on page 321.

There are few classes of concrete work where, at the expense of a little thought in designing movable forms, a great expense in lumber may not be saved.

Having estimated the quantity of lumber required for any given concrete job, and the number of times that it can be used, the labor cost of framing, erecting and taking down the forms may be calculated thus: With carpenters' wages at 25 cts. per hour, and laborers' wages at 15 cts. per hour, working 1 laborer to 2 carpenters, my records show that ordinary forms for walls, arches, etc., can be framed and erected for $6 per M ft. B. M., when men are working for a contractor. The forms can be carefully torn apart, taken down and moved a short distance, for $1.50 per M; making the total labor cost $7.50 per M. for each time that the forms are built up and torn down. Where the forms are built in panels and are not ripped apart and nailed together again at every move, there is only the cost of mov-

ing them each time after they have once been built, and this cost may not exceed 50 cts. per M for each move. There is another economic advantage in using forms in panels, namely, that they last longer. Indeed, there is hardly any limit to the number of times that a panel may be used. But when forms are torn apart each time, the nail holes and the battering due to hammers and pinch bars gradually bring the lumber to a state of unfitness.

For data of actual cost of forms consult the index under Concrete Forms and under Timberwork.

Cost of Lining and Plastering a Reservoir, Forbes Hill, Mass.—Mr. C. M. Saville is authority for the following cost data on the Forbes Hill Reservoir, Quincy, Mass., built by contract in 1900-1901. Common laborers were paid $1.50 per 10-hr. day. There were four classes of concrete used, and their itemized costs were as follows:

Class "A"; Concrete 1:2½:4.

1.35 bbl. Portland cement, at	$2.23	$3.01
0.46 cu. yd. sand, at	1.13	.52
0.74 " " stone, at	1.13	.84
25 ft. B. M. lumber for forms, at	20.00 per M.	.50
Labor, on forms		.59
" mixing and placing		1.15
" general expenses		.20
Total (279 cu. yds.) per cu. yd		$6.81

Class "B"; Concrete 1:3:6.

1.07 bbl. Portland cement, at	$2.23	$2.39
0.44 cu. yd. sand, at	1.13	.50
0.88 " " stone, at	1.13	.99
6½ ft. B. M. lumber for forms, at	20.00 per M.	.13
Labor, on forms		.21
" mixing and placing		.97
" general expenses		.15
Total (284 cu. yds.) per cu. yd		$5.34

Class "C"; Concrete 1:2:5:

1.25 bbl. natural cement, at	$1.08	$1.35
0.34 cu. yd. sand, at	1.02	.35
0.86 " " stone, at	1.57	1.35

4½ ft. B. M. lumber, at	20.00 per M.		$0.09
Labor, on forms			.10
" mixing and placing			1.17
" general expenses			.08
Total (400 cu. yds.) per cu. yd			$4.49

Class "D"; Concrete 1:2½:6½.

1.08 bbl. Portland cement, at	$1.53	$1.65
0.37 cu. yd. sand, at	1.02	.38
0.96 " " stone, at	1.57	1.51
1 ft. B. M. lumber, at	20.00 per M.	.02
Labor, on forms		.12
" mixing and placing		1.21
" general expenses		.18
Total (615 cu. yds.) per cu. yd		$5.07

Class "E"; Concrete 1:2½:4.

1.37 bbl. Portland cement, at	$1.53	$2.09
0.47 cu. yd. sand, at	1.02	.48
0.75 " " stone, at	1.57	1.17
12½ ft. B. M. lumber in forms, at	20.00 per M.	.25
Labor, on forms		.26
" mixing and placing		1.53
" general expenses		.15
Total (1,222 cu. yds.) per cu. yd		$5.93

In all cases the lumber was used more than once, so that the cost of the labor on the forms can not be computed per M. ft. B. M.

Class "A" was used for walls and floors of gate vault and gate chamber, and for cut-off walls.

Class "B" was used for the foundations of a standpipe.

Class "C," the only natural cement concrete on the work, was used for the lower layer of the bottom of the reservoir. Then came a layer of Portland cement plaster ½-in. thick, on which was placed the top layer of Portland cement concrete, Class "E." The slopes of the reservoir were lined in a similar manner, except that Class "D" was substituted for Class "C." The upper layer of concrete was laid in 10 ft. squares, alternate squares being laid and allowed to harden, and then the other squares were laid.

The cement was mostly Atlas, delivered in bags, four of which made a barrel, and assumed to be 3.7 cu. ft. All concrete, except on the sides, was made rather wet, and was kept wet for a week. The cost of laying with the ordinary concrete gang was as follows, wages being $1.50 per 10-hr. day:

	Cost per cu. yd.
2 men measuring materials	$ .15
2 " mixing mortar	.15
3 " turning concrete (3 times)	.22
3 " wheeling "	.23
1 " placing "	.07
2 " ramming "	.15
1 sub-foreman ($2.50)	.13
Total (20 cu. yds. per day)	$1.10

In addition to this gang there were 3 plasterers and 3 helpers working on the slopes. The ½-in. layer of plaster between the concrete layers was put down in strips 4 ft. wide and finished similar to the surface of a granolithic walk. This plaster was mostly 1:2 mortar with finishing surface of 1:4. Strips of coarse burlap soaked in water were used to keep this layer wet and cool; in spite of which some cracks appeared. This plastering gang averaged 2,100 sq. ft. per day, the cost being as follows for ½-in. plaster:

	Cost per 100 sq.ft.	Sq. yd.	Cu. yd
Cement at $1.53 per bbl	$1.15	$0.103	$7.42
Sand at $1.02	.13	0.012	.86
Burlap	.02	0.002	.14
Labor	.92	0.083	6.00
Totals	$2.22	$0.200	$14.42

Although plastering work is usually measured in square yards, I have computed it in areas of 100 sq. ft., and in cubic yards for purposes of comparison. It will be seen that it took more than 5 bbls. of cement per cu. yd. of this 1:2 mortar, and that it cost $6 per cu. yd. for the labor.

Returning again to the concrete, the stone was cobbles picked out of the hardpan excavated to make embankments. It was washed before crushing, anc had to be gathered up from scattered piles, which accounts in part for the high cost. It was crushed with a 9 × 15 Farrel crusher operated by a 12-HP. engine. The crusher was rated at 125 tons a day, but averaged only about 40 tons. The bin had a capacity of 30 cu. yds., divided into three compartments, one for stone less than 1½ diameter, one for stone between 1½ and 2½ ins., and the third for stone over 2½ ins. which had to be recrushed. The stone had about 46% voids and weighed 95 lbs. per cu. ft.

Cost of Lining a Reservoir at Canton, Ill.—G. W. Chandler gives the cost of a small concrete reservoir at Canton, Ill. Presumably the work was done by day labor, not by contract. The reservoir was built in the summer of 1901. It is 100 × 80 ft., 13 ft. deep and holds 12 ft. of water. The bottom is concrete, 10 ins. thick, including a ¾-in. coat of mortar. The footings of the side wall and the coping are of concrete. The concrete was 1:3⅓:7½. Voids in the stone were 40%, in the clean sand 30%. The sand and cement were mixed dry, then shoveled into a pile with the stone, well wetted, shoveled over again and shoveled into barrows. One 95-lb. sack of cement contained 0.9 cu. ft. The ¾-in. mortar coat was 1:2¼, spread and worked smooth with a trowel. The concrete cost as follows, per cubic yard:

0.857 cu. yd. stone, at $2.17	$1.86
0.856 bbl. cement, at $2.50	2.14
10.1 bu. sand (100 lbs. per bu.) at 5¾ cts	.58
Labor (wages 19 cts. per hr.)	.80
Total	$5.38

The stone weighed 2,500 lbs. per cu. yd.

The side walls built of paving brick (costing $6.50 per M. delivered) were laid in 1:2¼ cement mortar.

Cost of a Reservoir Floor, at Pittsburg, Pa.—Mr. Emile Low gives the following data:

The floor of the Highland Ave. Reservoir at Pittsburg, Pa., was covered in 1884 to a depth of 5 ins. with concrete, laid on a clay puddle foundation. The concrete mortar was made of 1 bbl. natural cement to 2 bbls. sand, mixed to a thin

grout in wooden boxes standing on legs. Five barrels of stone (sandstone) were spread on a platform of 2-in. plank, 10 × 16 ft., and the grout was poured over it, the whole mass being then turned over three times with shovels, then deposited to the depth of 5 ins. and rammed. The stone was quarried and hauled 20 miles by rail, then unloaded into small cars and hauled ½ mile to the reservoir. The sand was obtained in the reservoir limits, and cost merely the work of excavation, or 1¼ cts. per bushel.

The following was the cost of two days' work:

27 laborers, 2 days, at $1.25	$72.90
1 foreman, 2 days, at $2.50	5.00
Total, 101 cu. yds. at 77 cts	$77.90

During one month the labor cost was:

	Total cost.
642 days, laborers at $1.35	$866.70
17 " water-boy, at 60 cts	10.20
22 " foremen, at $2.50	55.00
Total, 1,302 cu. yds. at 71½ cts	$931.90

During another month 1,425 cu. yds. were laid at 95 cts. per cu. yd., wages being $1,25 a day.

The average cost of the 7,680 cu. yds. of 1:2:5 concrete was:

	Per cu. yd.
Quarrying stone	$ .45
Transporting "	.50
Breaking " (2½-in. ring)	.35
1⅓ bbl. natural cement	1.80
8 bu. sand	.10
Water	.05
Labor (wages $1.25 a day), mixing and laying	.75
Incidentals	.05
Total	$4.05

The contract price was $6 per cu. yd.

Cost of Lining a Reservoir.—Mr. G. L. Christian gives the following: In laying 3,000 cu. yds. of 1:3:6 concrete, 6 ins. deep, over the bottom of a reservoir, the wages paid were: Foreman, $2.50; laborers, $1.35; and teams $4 a day

The cost of blasting the rock is not included, but the cost of loading, hauling and crushing is included:

	Per cu. yd.
Sand	$ .37
Natural cement	1.10
Loading and hauling stone to crusher	.25
Labor at crusher, at $1.35 a day	.20
Rent of crusher	.01
Coal for crusher	.05
Hauling stone from crusher	.15
Foreman of concrete gang	.05
Laborers concreting, at $1.35	.50
Teams " at $4	.08
Total	$2.76
9% for supt., time-keeper, office help, etc	.24
Total	$3.00

The concrete was mixed very wet.

Cost of Concrete, Asphalt and Brick Reservoir Lining.—Mr. Arthur L. Adams gives the following data on the Astoria (Ore.) City Water-Works: The reservoir bottom is lined with 6 ins. of concrete (laid with expansion joints), ⅜-in. of cement mortar, one coat of liquid asphalt, and one harder asphalt coat. The lining of the slopes is the same except that a layer of brick laid flat, after dipping each brick in hot asphalt, was laid on the concrete. The bricks were laid on an asphalt coating and given a final asphalt coat. The actual cost per sq. ft. was:

Slope	Per sq. ft.	Bottom	
6-in. concrete	$0.1187	6-in concrete	$0.1031
1st coat asphalt	0.0100	Cement mortar finish	0.0113
Brick in asphalt	0.0889	1st coat asphalt	0.0077
2d coat asphalt	0.0131	2d coat asphalt	0.0082
Chinking crevices with asphalt*	0.0030		
Ironing	0.0035		
Total	$0.2372	Total	$0.1303

* These crevices developed near the top of the slope, due to sliding of the brick slope.

The detailed cost of this lining work was as follows:

The concrete was composed of basalt rock, quarried and

crushed near the work, of river gravel, sand and imported Portland cement. One cubic yard of concrete contained 0.9 cu. yd. stone, 0.5 cu. yd. gravel, 0.1 cu. yd. sand and 1 bbl. cement. There were 603 cu. yds. of concrete on slopes and 678 cu. yds. on the bottom. The work was well managed, each man averaging 1.84 cu. yds. per 10-hr. day, mixed and placed on the slopes, and 2.35 cu. yds. on the bottom. The men were Italians. The rock was quarried and crushed and delivered at the work (800 ft. haul) for 95 cts. per cu. yd. Sand and gravel were bought at 86½ cts. per cu. yd., and cement at $2.45 per bbl. All mixing was done by hand. There were three gangs of mixers, 6 men in a gang, supplied with materials by 9 wheelbarrow men (5 on rock, 3 on gravel and sand and 1 on cement). The 18 mixers placed the concrete for 6 men to rake and ram. Beside this force of 33 men, there were: 1 helper at the cement, 1 man tending water, 1 man sprinkling concrete already laid, 1 water-boy and 1 foreman. The gravel, sand and cement were mixed dry, then mixed wet, and stone added; the concrete was then turned three times, and once more when deposited. On the slopes a rough finishing coat of mortar was applied by taking a little mortar from the next batch. The concrete was mixed with very little water. By raking the coarse rock down the slopes and by using a straight edge before ramming, even slopes were secured.

On the bottom the ⅜-in. mortar (1:2) coat was applied by two finishers using smoothing trowels, and they were served by 4 men mixing and carrying the mortar.

On the slopes the concrete was placed in sheets 10 ft. wide from top to bottom; and on the bottom it was laid in squares, 20 ft. on a side; 2 × 6-in. planks being used to hold the free sides of the concrete. When a new square was laid adjoining an old square, the 2 × 6 pieces were removed, and replaced by a piece of ½ × 4-in. weather boarding. Two weeks later these ½-in. strips were removed so that the grooves could be run full of asphalt. The ½-in. strips should be beveled and laid with the wide edge up, or they will be removed with difficulty. The labor cost of concreting was $1.07 per cu. yd. on the slopes and 67 cts. on the bottom, wages being 15 cts. an hour.

Two grades of Alcatraz asphalt were used: the L and the XXX, or paving brand. The L grade is a natural liquid

asphalt, and the XXX grade is the product of refining the natural rock asphalt with about 20% of the liquid as a flux; they are sold in barrels holding 400 lbs. No asphalt was placed on the concrete until it had been in place two weeks and was dry on the surface. On the bottom of the reservoir the first coat applied was the L grade, the second coat was the XXX grade. On the slopes none of the L grade was used, because of its tendency to creep; moreover, the harder asphalt when at the proper temperature runs readily and fills all crevices. The only advantage of the L grade is that it will adhere to a damp surface where the XXX will not.

For best results all work should be done in the dry summer months. All dust must be carefully swept off the concrete as it prevents bonding with the asphalt. The asphalt applied with mops made of twine, was delivered in sheet-iron buckets by attendants who carried it from two melting kettles holding 3,000 lbs. each.

The bricks used on the slopes were half vitrified and half common, due to inability to get the full number of vitrified bricks. They were submerged in a bucket of hot asphalt and placed on the slope with iron tongs; a common laborer, after a little practice, readily averaged 2,300 bricks laid in 10 hrs. A push joint was made. To secure close joints and consequent economy in asphalt, the asphalt must be kept hot enough to run like water.

The asphalt finishing coat followed the brick laying as closely as possible, to avoid delays due to rain-water standing in open joints. The slope was ironed with hot irons to improve the appearance. Overheating of the irons is apt to injure the asphalt. During hot weather the brick slid on the slope somewhat by closing up thick joints laid in colder weather; but all motion ceased in a few weeks. The advantage of asphalt lies in retarding the passage of water through brick or concrete; it does not exclude water, for an asphalt coated brick submerged in water will eventually absorb as much water as an uncoated brick.

Cost of First Asphalt Coat on Concrete Slopes (29,637 sq. ft.)

Labor:	Total cost.	Cost per sq. ft.
Building sheds......	$5.00	$0.00017
Spreading, 91 hours at 20 cts...............	18.20	0.00061
Boiling, 91½ " 15 cts...............	13.72	0.00046
Helpers, 73½ " 15 cts...............	11.02	0.00037
Sweeping, 49⅔ " 15 cts...............	7.43	0.00025

Materials:	Total cost.	Cost per sq. ft.
Asphalt, 19,243 lbs. at $0.1225	$235.73	$0.00795
Fuel, 1 cord wood at $2.50	2.50	0.00009
Hauling 9.6 tons asphalt at $0.47	4.50	0.00015
Totals	$298.10	$0.01005

Cost of Asphalt Finishing Coat on Slopes (29,637 sq. ft.)

Labor:	Total cost	Cost per sq. ft.
Building sheds	$5.00	0.00017
Spreading, 95¾ hours at 15 cts	14.36	0.00049
Boiling, 73¼ " "	10.99	0.00037
Helpers, 144½ " "	21.68	0.00073
Sweeping, 20 " "	3.00	0.00010
Foreman, 60 " 25 cts	15.00	0.00051
Materials:		
Asphalt, 25,230 lbs. at $0.01225	309.07	$0.01042
Fuel, 1 cord	2.50	0.00008
Hauling 12.6 tons at $0.47	5.92	0.00020
Totals	$387.52	$0.01307

Cost of Ironing Asphalt Slope (29,637 sq. ft.)

Labor;	Total Cost	Cost per sq. ft.
Ironers, 295.5 hours at 15 cts	$44.33	$0.00150
Heaters, 75 " "	11.25	0.00038
Helpers and sweeping, 34½ hrs. at 15 cts.	5.18	0.00017
Foreman, 49½ hours at 25 cts	12.37	0.00042
Materials:		
Irons, 20 at $1.50	30.00	0.00101
Fuel, 1 cord at $2.50	2.50	0.00008
Totals	$105.63	$0.00356

Cost of First Asphalt Coat on Concrete Bottom (34,454 sq ft.)

Labor:	Total cost	Cost per sq. ft.
Building sheds, 25 hrs. at 20 cts	$5.00	$0.00015
Spreading, 38 " 20 cts	7.60	0.00022
Boiling, 37 " 15 cts	5.55	0.00016
Helpers, 43 " 15 cts	6.45	0.00019
Sweeping, 44 " 15 cts	6.60	0.00019
Materials:		
Asphalt, 18,490 lbs. at $0.01225	226.50	0.00658
Fuel, 1 cord	2.50	0.00012
Hauling, 9.25 tons at $0.47	4.35	0.00007
Totals	$264.55	$0.00768

Cost of Second Asphalt Coat on Bottom (34,454 sq. ft.)

	Total cost	Cost per sq. ft.
Labor:		
Building sheds	**$5.00**	$0.00015
Spreading, 35 hrs. at 15 cts	**5.25**	0.00015
Boiling, 30 " "	**4.50**	0.00013
Helpers, 52½ " "	**7.88**	0.00023
Sweeping, 44½ " "	**6.68**	0.00020
Foreman, 17½ " 25 cts	**4.38**	0.00013
Materials:		
Asphalt, 19,591 lbs. at $0.01225	**239.99**	0.00702
Fuel, 1 cord at $2.50	**2.50**	0.00007
Hauling, 9.8 tons at $0.47	**4.61**	0.00013
Totals	**$280.79**	**$0.00821**

Cost of Laying Brick on slopes (132,000 bricks **dipped in Asphalt and laid** flat; 29,637 sq. ft.).

	Total cost.	Cost per M.
Labor:		
Unloading brick from barge, 290 hrs. at 15 cts. " " foreman, 22 " 25 cts.	**$49.00**	**$0.37122**
Hauling and storing, 160 hrs. at 35 cts. and 140 hrs. at 55 cts	**152.43**	**1.15473**
Laying, 561 hrs. at 15 cts	**84.15**	**0.63750**
Attendance, 1,341 hrs. at 15 cts	**201.15**	**1.52387**
Boiling Asphalt, 220 hrs. at 15 cts	**33.00**	**0.24500**
Foreman, 96 hrs. at 25 cts	**24.00**	**0.18180**
Materials:		
Brick, 132 M at $7.00	**924.00**	**7.00000**
Asphalt, 93,372 lbs. at $0.01225	**1,143.81**	**8.66516**
Asphalt haul, 46.7 tons at $0.47	**21.95**	**0.16628**
Totals	**$2,633.49**	**$19.95055**

Cost of Fortification Work, at Fort Point, Cal.—In Jour. Assoc. Eng. Soc., Vol. XIV., 1895, p. 239, George H. Mendell gives the following data: The work was the construction of fortifications at Fort Point, near San Francisco. The following experiments were made:

	Experiment No. 1 cu. ft.	Experiment No. 2 cu. ft.	Experiment No. 3 cu. ft
1 bbl. Portland cement measured loose	**4.42**	**4.58**	**4.5***
Water added	**2.00**	**1.75**	**1.92**
Volume of stiff paste resulting	**4.00**	**3.80**	**3.82**
Moist sand added	**10.12**	**11.40**	**13.50**
Water added	**2.00**	**2.50**	**2.00**
Volume of mortar resulting	**10.12†**	**12.30**	**14.00**
Gravel added‡	**36.50**	**36.90**	......
Volume of loose concrete	**45.25**	**43.23**	......
Volume of concrete tamped in place	**37.50**	......	......

*** This barrel measured 3½ cu. ft. packed.**

† There is some doubt as to the accuracy of this measurement, for it was recorded as 9.12 cu. ft., although it was probably 10.12.

‡ This gravel in experiment No. 1, was in ¾-in. sizes down to birdshot; in experiment No. 2 it was the size of beans and smaller. There was a considerable percentage of what should be called sand in the gravel, probably 20%.

In making the concrete all materials were measured loose and a barrel of cement was assumed to measure 4½ cu. ft. The proportions of a batch were 1:3:8; the 8 being 8 × 4½, or 36 cu. ft. of stone and gravel. In making a mass of concrete 60 ft. long, 40 ft. wide and 30 ft. high, a careful record was kept of the cost of several weeks' work, measuring 1,825 cu. yds. in place:

	Cost, per cu. yd.
0.73 bbl. cement at $2.50	$1.82
0 83 cu. yd. stone	1.40
0.26 " " gravel	.35
0.31 " " sand	.29
Water	.04
Crushing stone,* mixing and placing concrete.	.80
Total	$4.70

* While it is not definitely stated I infer from what is said that the labor of crushing was about 15 cts.

Wages were $2 per day of 8 hrs. for laborers, and $4 for foremen. The cost of timbering and incidental expenses is not included other than the pay of the men and the foreman. The total volume of all the loose materials, exclusive of the water, was 2,767 cu. yds. before mixing; after mixing, and measured in cars holding 20 cu. ft. each, the volume was 2,433 cu. ft.; after being rammed in place the volume was 1,825 cu. yds. The shrinkage of the concrete under the ramming was therefore 25%. A number of experiments were made on single carloads which showed that a carload of 20 cu. ft. of loose concrete made 15 to 15½ cu. ft. compacted in place.

The stone was quarried at Angel Island, and delivered on the wharf in sizes suitable for a Gates crusher, hauled in wagons to the crusher, which delivered it to the mixer, into which all the ingredients were fed from hoppers automatically. The mixer was of the cylindrical continuous type, and there was difficulty in delivering the materials to it automatically and in the desired proportions. The concrete was delivered by the mixer into cars holding 20 cu. ft. When a car was filled, the door of the mixer was closed for a minute, during which minute another car was put in place, the concrete in the meantime accumulating in the mixer. The cars were pushed by men to the place of deposit, a

variable distance of 300 to 600 ft., and discharged through a trestle having an extreme height of 30 ft., gradually diminishing to 4 ft. The concrete was then shoveled into wheelbarrows and wheeled 20 to 40 ft.

During the month of Aug., 1892, concrete was mixed by hand by a gang of 20 men under 1 foreman. The average 8-hr. output was 45 cu. yds. of concrete at a cost of $1 per cu. yd. for mixing and placing, wages being $2 a day. A batch consisted of 4 bbls. of cement and 144 cu. ft. of gravel and stone, giving 144 cu. ft. of concrete. The materials were piled conveniently around the mixing platform. The stone and gravel were delivered in barrows and spread to an even thickness on the platform. Upon this the sand was wheeled and spread with a straight edge. The cement, also leveled, formed the top layer. Water was added in the turning. The materials were turned twice with shovels, being well dispersed in turning. A third turning resulted from shoveling the concrete into wheelbarrows, and a fourth turning in distributing the concrete. There was no ascent and the distances were short in wheeling the concrete, and the men were a picked lot.

Cost of Fortification Work.—Mr. L. R. Grabill is authority for the following cost data: The work was upon fortifications built in 1899 for the U. S. Government, and was done by contract, working 8 hrs. per day. The following is the average for 9,000 cu. yds.:

	Per day.	Per cu. yd.
6 laborers wheeling materials to board..	$7.50	$ .16
8 " mixing	10.00	.21
8 " wheeling away	10.00	.21
6 " placing and ramming........	7.50	.16
1 pumpman..........................	1.25	.02
1 water-boy..........................	1.00	.02
1 foreman..........................	2.00	.04
Total, 48 cu. yds. a day............	$39.25	$ .82

Each batch contained ¾ cu. yd. of 1:2:2:3 concrete, and was turned four times.

The cost of mixing 4,000 cu. yds. in a machine mixer by day labor (not by contract) was as follows:

	Per day.	Per cu. yd.
32 laborers	$40.00	$ .34
1 pumpman	1.25	.01
1 teamster and horse	2.00	.02
2 water-boys	2.00	.02
1 engineman	1.70	.02
1 derrick tender	1.50	.01
1 fireman	1.50	.01
1 foreman	2.88	.03
Fuel (cement barrels, largely)	1.25	.01
Total, 118 cu. yds. per day	$54.08	$ .47

The average 8-hr. day's work was 168 batches of 0.7 cu. yd. each. The best day's work was 200 batches. Seven revolutions of the 4-ft. cubical mixer were sufficient. A 12-HP. engine operated the mixer and served also to hoist the material cars up the incline to the mixer. These cars were loaded through trap doors in a bin containing the materials, then the cement was placed upon the load. The material cars moved up one incline, dumped, and passed down another incline on the opposite side. The concrete was dumped into an iron bucket resting on a car, hauled to one of the two boom derricks. These derricks had 80-ft. booms and were swung by bull-wheels. This plant cost about $5,000. The concrete was rammed in 6-in. layers in all cases; and it was found advisable to have one rammer to every 20 batches deposited per day, in addition to the spreaders.

Cost of Concrete Breakwater, Buffalo, N. Y.—Mr. Emile Low gives the following data on the cost of making concrete by contract for the Buffalo Breakwater, in 1902: A 5-ft. cubical mixer was mounted on a scow and run by a 9 × 12-in. horizontal engine. The concrete was 1:2:1:4 cement, sand, gravel and stone. The voids in the sand and gravel were 27%, in the unscreened limestone, 39%. A bag of cement was assumed to be 0.9 cu. ft. The materials were stored in canal boats alongside. The sand was loaded by 3 shovelers into wheelbarrows holding 3.6 cu. ft. each, and wheeled in tandem to a steel charging bucket. Two more barrows, each holding 2.7 cu. ft. of gravel, were loaded and also dumped into the charging bucket; then 6 bags of cement (1½ bbls.) were emptied into the bucket. Another bucket

was loaded with 21.6 cu. ft. of stone by 8 shovelers. These two buckets were hoisted by a derrick, in rapid succession, and dumped into the mixer. The dump man also attended to supplying water. A charging man started the mixer. The concrete was dumped from the mixer into a skip on a car below, by 2 men who pushed the car out where another derrick on the mixer scow hoisted it to the wall. There were 2 tagmen on each derrick to swing the booms, one paying out a tag rope while the other hauled in. A parapet wall, containing 841 cu. yds., was built in 46 hrs. actual work, 18.2 cu. yds. being placed per hour, each batch containing 1.07 cu. yds. of rammed concrete. A parapet deck, containing 1,720 cu. yds., was built in 88 hrs., or 19½ cu. yds. per hr., each batch being 1.08 cu. yd. The labor cost of making this concrete (common labor being $1.75 per 10 hrs.) was as follows:

	Concrete	
	Cost, per 10-hr. day.	Cost, per cu. yd.
Loading gang:		
1 assistant foreman	$2.00	$0.011
3 cement handlers	5.25	0.029
3 sand shovelers	5.25	0.029
2 gravel "	3.50	0.020
8 stone "	14.00	0.076
1 hooker-on	1.75	0.010
Mixer gang:		
1 dumpman	1.75	0.010
1 charging man	1.75	0.010
2 car men	3.50	0.020
2 engine men, at $3.25	6.50	0.035
4 tag men, at $2.00	8.00	0.044
1 fireman	2.00	0.011
Wall gang:		
1 signalman	1.75	0.010
1 dumper	1.75	0.010
6 shovelers, at $2.00	12.00	0.065
4 rammers	7.00	0.038
1 foreman	4.00	0.022
Total (182 cu. yds. per day)	$81.75	$0.450

This cost of 45 cts. per cu. yd. does not include fuel, forms or plant rental.

Cost of Concrete Locks, Coosa River, Ala.—Mr. Charles Firth gives the following on the concrete locks on the Coosa River, Ala. Lock No. 31 has a length of 322 ft. between hollow quoins and a length of 420 ft. over all, with a width of 52 ft. in the clear. The lock walls are 34.7 ft. high and 16 ft. thick at the base. The total quantity of concrete was 20,000 cu. yds., requiring 21,500 bbls. of cement, half Atlas and half Alsen's. It was mixed 1:3:5½, the stone being crushed mica-schist. Two mechanical 4-ft. cube mixers were used, being driven by a 10 × 16 engine. Each batch consisted of 3 cu. ft. cement, 9 cu. ft. sand and 16½ cu. ft. stone, and was turned 4 times before and 6 times after adding the water, at a speed not exceeding 8 revolutions per minute. The top floor of the mixing house had a storage capacity of 2,000 bbls. of cement. The sand and stone were delivered in side dump-cars. The concrete was delivered into bottom-dump cars. The average output of these two mixers was 200 cu. yds. in 8 hrs., or 100 cu. yds. per mixer, but it was limited by the means of placing the concrete. Each batch of concrete measured 24 cu. ft. in the car, but it shrank 20% when rammed in place, so that it required 34 cu. ft. of concrete in the cars to make 1 cu. yd. in place. The concrete was mixed quite dry and rammed in 6 to 8-in. layers, using 30-lb. iron rammers having a square face 6 ins. on a side. On all exposed surfaces a 1:3 mortar was placed as the work progressed, making a thickness of 6 ins. of mortar. To do this 2 × 12-in. planks were placed 4 ins. away from the forms, being kept at that distance by 2 × 4-in. strips of wood. After the backing concrete was in place and partly rammed, these planks were removed and the 6-in. space filled with mortar. The walls were carried up in lifts, each lift being completed all around the dock before the next was commenced. The first lift was 10.7 ft. high; each succeeding lift was 6 ft., except the last which was 4.5 ft., exclusive of the 18-in. coping. The coping was 5 ft. wide and made in separate blocks 3 ft. long, which were placed after the walls were completed. The coping was 1:2:3 concrete, faced with 1:1 mortar, and was cast in blocks face down, its edges being rounded to a 3-in. radius. The sides of the molds for these blocks were removed 3 days after making, and 10 days later the blocks were stacked away.

In building the forms 6 × 8-in. posts 24 ft. long were set up on the inside of the lock in line, 5 ft. 7 ins. apart; and a similar row of posts 12 ft. long was set up outside of the lock. The posts were capped with 6 × 8-in. caps which supported the track stringers for the concrete cars. Each line of posts was sheeted with 3 × 10-in. plank dressed on all sides, and the posts were well braced with inclined struts. After the first lift was completed, the back row of posts was lifted onto the offset left on the back of the wall by the reduced width of the next lift; but the long posts on the front face were not moved, the caps being simply unbolted from them and fastened near the top of the posts. The sheeting plank was of course moved up. No tie bolts were built into the concrete wall, which made the bracing of the forms rather elaborate as the wall grew higher.

The bottom-dump concrete cars were dumped onto wooden platforms inside the forms, as it was found that even a slight drop caused the larger stones to separate and roll to the outer edges. These stones were shoveled back into the pile, and then the concrete was placed with shovels. The doors of the cars were hung at the sides, and upon dumping they would strike the stringers carrying the track, thus jarring the forms and frequently throwing them out of line. A better method would have been to have hinged the doors at each end of the car. It was found advisable to have plenty of head room at the end of each lift, otherwise the spreading and ramming were not properly done. During the year ending June, 1895, there were only 90 days when work was carried on uninterrupted by floods. The total quantity of concrete placed that year was 8,710 cu. yds., the work being done by day laborers for the Government (not by contract). Negroes at $1 per 8-hr. day were employed. The cost per cubic yard of 1:3:5½ concrete was as follows:

1 bbl. cement	$2.48
0.88 cu. yd. stone, at $0.76	.67
0.36 " " sand " 0.34	.12
Mixing, placing and ramming	.88
Staging and forms	.42
Total, per cu. yd	$4.57

Had wages been $1.50 per day the cost would have been $1.32 per cu. yd. instead of 88 cts. for mixing.

Cost of Concrete Locks, I. & M. Canal.—Mr. J. W. Woermann gives the following data relating to the building of concrete locks for the Illinois and Mississippi Canal: The work was done in 1892 to 1894 by day labor for the Government, the working day being 8 hrs. long. The stone was a flinty limestone without bed, or at best in thin irregular strata unfit for even good rubble masonry. In addition to the concrete locks there were several concrete abutments for two timber dams, and these will be described first.

Abutments: The forms for the first two abutments were erected in sections, alternate sections being erected and filled with concrete. When the concrete had set, the forms were removed and the forms for the intermediate sections were erected and braced against the concrete already in place. It was found impossible to secure good alinement of the concrete faces in this way, so the forms for subsequent work were erected all at once. The two abutments on Carr's Island were L-shaped, the side next to the river being 40 ft. long, and the side extending into the earth 20 ft. long. The top thickness was 3 ft., the front was vertical, the base had a thickness equal to 0.4 the height of the wall, the back of the wall being stepped. Each dam abutment was built in four sections, each of which contained 30 cu. yds., which constituted an 8-hr. day's work for a gang of 26 men distributed as follows:

	Per day.	Per cu. yd.
2 handling cement and measuring sand.	$3.00	$ .10
3 filling barrows with gravel and stone..	4.50	.15
8 mixing with shovels..................	12.00	.40
2 shoveling concrete into barrows........	3.00	.10
5 wheeling concrete to forms............	7.50	.25
1 spreading concrete	1.50	.05
5 tamping concrete.....................	7.50	.25
Totals............................	$39.00	$1.30

Cost of 254 cu. yds. of concrete in two abutments on Carr's Island:

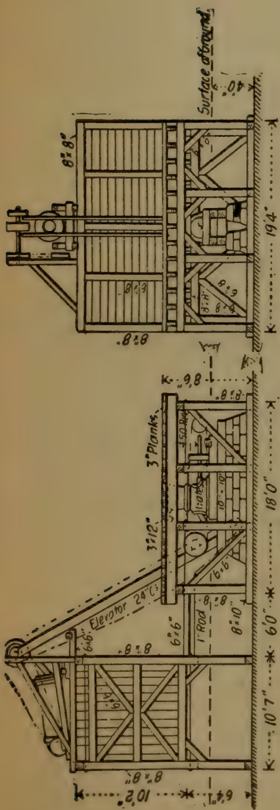
	Per cu. yd.
1.65 bbls. of Portland (Germania) cement........	$5.60
0.5 cu. yd. crushed stone........................	2.07
0.24 " " gravel	.59
0.53 " " sand	.24

Lumber for forms, and warehouse and platforms (charging ¼ of first cost of, $18 per M).....	$ .55
Carpenter work* ($9 per M)	1.10
Mixing and placing concrete.....................	1.47
20% of first cost of plant.........................	.31
Engineering and miscellanies...................	.31
Total..	$12.24

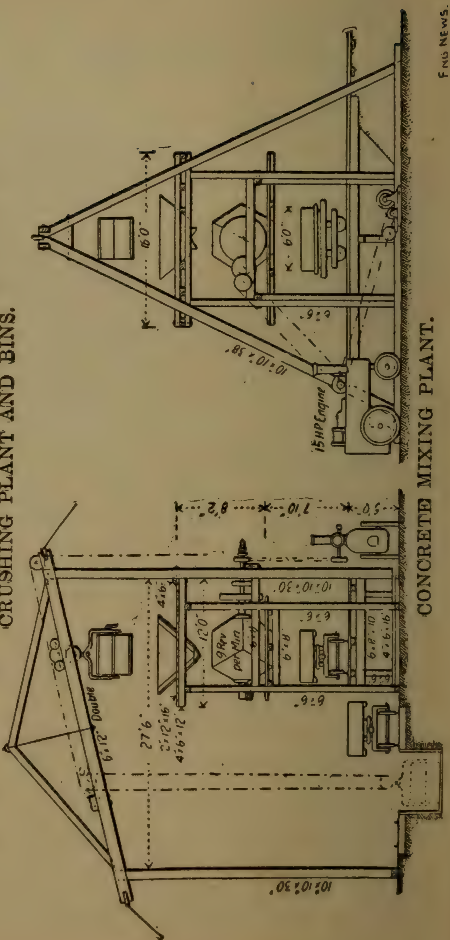
It will be noted that the amount of cement, 1.65 bbls. per cu. yd., as above given, was exceedingly great. This was due to facing the abutments with a 1:2 mortar 8 ins. thick! The body of the wall was made of 1 part cement, 2 parts sand, 2 parts gravel, and 2 parts broken stone. The cement was measured loose, one barrel of packed cement (Alsen's) containing 3.6 cu. ft. made 4.5 cu. ft. of loose cement. A barrel of cement weighed 395 lbs. gross, or 370 lbs. net. The concrete was mixed quite dry and well rammed, the ramming alone costing nearly 30 cts. per cu. yd. The cost of mixing was high, but this is to be expected where men are working by the day for the Government. The sand and cement were turned over 3 times with shovels and spread out; then gravel was spread over, and finally the stone; the mass was turned over at least 4 times with shovels, the last turn landing it in the wheelbarrow. The forms consisted of 2 × 8-in. studs placed upright, 2 ft. between centers, and faced with 2 × 8-in. plank dressed on both sides. Braces of 4 × 6-in. stuff were used.

Locks: The concrete for the locks was mixed by a mechanical mixing plant, shown in Fig. 14. A queen truss was supported by two A-frames, one of the frames having legs 30 ft. long, the other having legs 38 ft. long. A pit was dug under the truss, and tracks laid on each side of the pit so that dump cars could readily deliver materials into a charging box placed in the pit. The charging box was 3 ft. 8 ins. square inside and 3 ft. deep, holding 40 cu. ft., and was raised by a ½-in. steel cable running through a pair of double blocks. The slope of the lower chord of the truss was such that the cable hoisted the bucket and carried it along the truss without the use of any latching devices.

* Carpenters received $2.25 a day and laborers $1.50; there was one aborer to two carpenters.



CRUSHING PLANT AND BINS.



CONCRETE MIXING PLANT.

This, it should be noted, is a very simple and ingenious hoisting and conveying apparatus. A 15-HP. portable engine operated the hoist with one pulley, and its other pulley operated the friction clutch driving the 4-ft. cubical concrete mixer. Above the mixer was a hopper, and under the mixer the track for the dump cars that carried the concrete to the lock walls. It was found necessary to lower the hopper 6 inches lower than shown so as to obviate spilling the materials. It was also found desirable to reduce the distance between the mixer and the lower platform by 9 ins., and to place diagonal timber braces under the timbers supporting the axles of the mixer. Nine revolutions of the mixer secured a perfect mixture of the concrete. It was found that the mixer did not mix the 1:2 mortar for the facing satisfactorily, so it was mixed with shovels. The belt hoist, trolley, charging box, and cubical mixer, with the necessary shafting, gearing, etc., cost $706 delivered, and the timber, framing and erection cost $300 more. The framework was put together with bolts so as to be readily moved from site to site.

The crushing plant consisted of a No. 2 Gates crusher, delivering to a bucket belt elevator. The broken stone was hauled in dump cars, into which the proper amounts of sand and cement were also loaded. The cars delivered the materials into the charging box as above described. The concrete was hauled over a trestle in cars to the forms.

The average force engaged in operating the plant, not including the men engaged in rock crushing, was as follows on the first lock built, namely, the "guard lock":

	Men.	Per cent. of cost.
Handling cement	3	5.26
Filling and pushing sand car	5	8.77
" " " stone car	9	15.79
Measuring water	1	1.75
Dumping bucket on top platform	3	5.26
Opening and closing door of mixer	1	1.75
Operating friction clutch	1	1.76
Attending concrete cars under mixer	1	1.76
Dumping cars at forms	2	3.51
Spreading concrete in forms	3	5.26
Tamping " " "	10	17.54

	Men.	Per cent. of cost.
Mixing mortar for facing (with shovels)....	6	10.53
Finishing top of wall	2	3.51
Hauling concrete cars (with 1 horse)........	1	3.51
Engineman operating hoist..................	1	3.51
" " engine................	1	3.51
Foreman	1	3.51
General foreman...............................	1	3.51
Totals......................................	52	100.00

The percentage of total cost is calculated upon the assumption that each laborer received one half as much wages as each engineman, foreman, and driver with horse, per 8 hrs., which would make the total daily wages equivalent

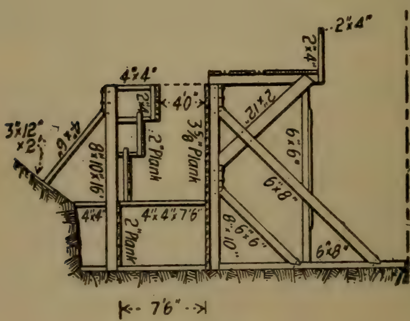


FIG. 15.

to the wages of 57 men. Wages of common laborers were $1.50 a day. The output of this force per 8-hr. day was 60 batches of concrete and 40 batches of facing mortar, requiring in all 100 bbls. of cement. The concrete consisted of 1 bbl. Alsen's cement (4.5 cu. ft. measured loose), 10 cu. ft. sand, and 20 cu. ft. of broken stone. It is probable that this mixture did not yield more than 0.85 cu. yd. of rammed concrete per batch. The 1:2 mortar was 1 bbl. cement to 9 cu. ft. sand, and probably one batch did not much exceed

0.33 cu. yd. If these assumptions are correct the daily output was about 51 cu. yds. of concrete mixed in the mixer beside 13 cu. yds. of facing mortar mixed by hand—a very poor showing considering the excellent plant and large number of men. The 9 men filling and pushing the stone cars must have shoveled the stone off the ground, for otherwise, with a comparatively short haul, one or two men and a horse could have delivered all the stone from bins. As it was, each of the 9 men handled less than 6 cu. yds. per day! Note also that each of the cement men handled only 33 bbls., or 5½ cu. yds., of cement per day. Note the high cost of ramming the concrete.

There were 2,213 cu. yds. of concrete in the lock walls, and 1,550 cu. yds. in culverts, foundations, etc., requiring 1.4 bbls. cement per cu. yd. The cost of mixing and placing was $1.77 per cu. yd. There were 145,000 ft. B. M. pine timber used in forms, trestles, etc. (Fig. 15), the first cost of which was $18 per M., one-quarter of which was charged up to this lock, as the lumber was used for four locks.

The cost of building lock No. 36, containing 2,140 cu. yds. of concrete (1,820 cu. yds. of which was in the lock walls) was as follows:

	Total cost.	Cost per cu. yd.	Per cent. of cost
3,010 bbls. Alsen's cement, at $3.02....	$9,057	$4.23	47%
1,377 cu. yds. broken stone, at $1.37...	1,922	0.90	10
398 " screened pebbles, at $0.90	354	0.17	3
459 " gravel, at $0.67...........	310	0.15	
500 " sand, at $1.78............	889	0.42	5
150,000 ft. B. M. timber for forms and warehouse (charging one-fourth the cost of $16 per M).....................	600	0.28	3
Carpenter work on forms, trestles, etc. ($10 per M)...........................	1,472	0.68	8
Fuel, lights, repairs, etc................	253	0.11	1
Mixing and placing concrete............	3,897	1.82	20
20% of cost of plant.....................	650	0.30	3
Total.........................	$19,404	$9.06	100%

On lock No. 37, which had walls 25 ft. high, 4 ft. wide at the top and 11 ft. wide at the bottom (uniformly battered on the back), a gang of 58 men on each shift averaged 65 batches of concrete and 31 batches of face mortar, or 86.2 cu. yds. of wall per 8-hr. day. There were 3,767 cu. yds. in this work, and 180,000 ft. B. M. of timber were used in the forms, trestles, etc. The work of erecting and taking down this timber cost $14 per M. The labor of mixing and

placing the concrete cost $1.64 per cu. yd., including engineering. It is not clear why this item of cost should have been much exceeding $1 per cu. yd., for, as above stated, 58 men averaged 86 cu. yds. a day.

Each batch of concrete contained 5 1/7 cu. ft. of Alsen's cement (measured loose), 16 cu. ft. of a mixture of sand and gravel, and 20 cu. ft. of broken stone. This batch made exactly 1 cu. yd. measured in the wall. Three 8-hr. shifts were worked each 24-hr. day, with 65 men in each shift. The organization of each gang was the same as given on page 307, except that the force of tampers was doubled, as it had been found that they had limited the daily output on previous work. The average output per shift was 76 batches of concrete and 35 batches of face mortar, the best shift's record being 96 batches of concrete and 22 batches of face mortar. One wall containing 973 cu. yds. was built in 10 shifts, or 97.3 cu. yds. per shift. The two lock walls were each 238 ft. long, 4 ft. wide on top, 7½ ft. wide at the base, and 16 ft. high, and were built in sections 22 ft. long. The forms, Fig. 15, were made of pine, the uprights being 8 × 10-in., spaced 4 ft. center to center, and were sheeted with 4-in. dressed pine on the face, and 2-in. rough pine on the back of the walls. The uprights were braced by 6 × 8-in. inclined braces. A trestle was provided for concrete dump-cars to run upon, as shown. It will be noted that the timbering throughout was exceedingly heavy. The reason for this is said to have been that lighter forms had yielded in places; and that, in view of the shocks that would occur in dumping the concrete from cars, it was not deemed advisable to use light forms. However, I have seen concrete dumped into light forms (2-in. plank and 4 × 6-in. uprights) from cars at much greater heights that in this lock work, yet without injury to the forms. The secret lies in proper bracing and fastening. The use of more than 70 ft. B. M. of timber for each cubic yard of concrete in heavy work like this shows great extravagance. In fact, there is scarcely an item, except the stone and sand, that was not costlier than it would have been by contract work. The cement used amounted to 1.4 bbl. per cu. yd. of wall. This excessive amount was due to facing the walls with a 1:2 mortar, 8 ins. thick, and costing $16 per cu. yd. Mortar 2 ins. thick would have served just as well.

Since the foregoing was written I have received from Mr. Woermann the following interesting data which show how the cost of more recent lock work has been reduced. Mr. Woermann says:

"If any criticism was to be made of the concrete masonry erected in 1893 and 1894, it would probably be to the effect that it was too expensive. The cost of the masonry erected during those two seasons was $8.00 to $9.00 per cubic yard. Our records showed that about 45% of this cost was for Portland cement alone, and, moreover, that 40% of the total cement used at a lock was placed in the 8-in. facing and 5-in. coping. So in the seven locks erected in 1895 on the eastern section, the facing was reduced to 3 ins. and the proportions changed from 1:2 to 1:2½.

"In 1898 this cost received another severe cut, and Major Marshall's instructions stated that the facing should not exceed 1½ ins. in thickness nor be less than ¾-in., while the layer of fine material on top of the coping was to be only sufficient to cover the stone and gravel. The amount of sand was again increased so that the proportions were 1:3.

"The cost of the Portland cement concrete was likewise cheapened by increasing the amount of aggregates. On the earlier work the proportions were 1:2:2:3, while on the work in 1898 the proportions were 1:4:4. The cost of the walls was further cheapened by using Utica cement in the lower steps of the wall, with 2 ft. of Portland cement concrete on the face. The proportions used in the Utica cement concrete were 1:2½:2½. This lower step is one-third of the height, or about 7 ft.

"The forms were of the same character as those used on the first locks, except that for lining the inner face, 3 × 10-in. hard pine planks were substituted for the 4 × 8-in. white pine. The hard pine was damaged less by the continuous handling, and the cost was practically the same. There was also an important change made in the manner of fastening the plank to the 8 × 10-in. posts. A strip 1¾ ins. square was thoroughly nailed to each post, once for all, with 20d. spikes, and the planking was then nailed from the outside, as shown in Fig. 16. This kept the face of the plank in a perfectly smooth condition, and prevented the formation of the little knobs on the face of the concrete which represented all

the old nail holes. This style of forming was also easier to take apart after the setting of the concrete. Rough pine planks, 2 × 12-in., were used for the back of the form, the same as before.

"In order to keep ahead of the concrete force it was necessary to use two gangs of carpenters, erecting the forms for the next two locks. Each gang consisted of about 20 carpenters (at $2.25) and 10 helpers (at $1.50); but men were transferred from one to the other, according to the stage of completion of the two locks. In addition to these two gangs, two carpenters were on duty with each concrete shift to put in the steps in the back of the forms. Sufficient lumber was required for the forms for three complete locks, and 14 locks (Nos. 8 to 21) were built.

"The same type of mixer has been used as on the earlier

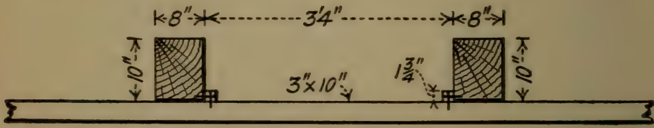


FIG. 16.

work at Milan, namely, a 4-ft. cubical steel box mounted on corners diagonally opposite. On account of the greater number of locks to be built on the eastern section, however, two mixers were found necessary, so that while the concrete force was at work at one lock, the carpenters and helpers were erecting the mixer at the next lock. The facing was mixed by hand. After turning over the dry cement and sand at least twice with shovels, the mixture was then cast through a No. 5 sieve, after which the water was incorporated slowly by the use of a sprinkling can so as to avoid washing. The secret of good concrete, after the selection of good materials, is thorough mixing and hard tamping. Each batch of concrete, consisting of about 1.2 cu. yds. in place, was turned in the mixer for not less than 2 mins. at the rate of 9 revolutions per minute. The amount of tamping is indicated by the fact that about 16 men out of 72 on each shift did nothing but tamp. The rammers used were 6 ins. square and weighed 33 lbs. The bottom of the rammer consisted of three ridges, each 1-in. in height, so as to make more bond between the successive layers.

"On the eastern section the top of the lock walls was higher above the ground, as a rule, than at the Milan locks, and the cars were run up an incline with a small hoisting engine. A 15-HP. portable engine and boiler operated the bucket hoist from one pulley, the mixer from the other pulley, and also furnished steam for the hoist which pulled the cars up the incline. The incline made an angle of about 30° with the ground. The practice of carrying on two sections at once was continued the same as on the western section. Each main wall was systematically divided into 11 sections, making each section about 20 ft. long. The corners of the coping were dressed to a quadrant of about 3 ins. radius with a round trowel like those used on cement walks. In fact, the whole method of finishing the coping was the same as is used on concrete walks. The mortar was put on rather wet and then allowed to stand for about 20 mins. before finishing. This allowed the water to come to the surface and prevented the formation of the fine water cracks which are sometimes seen on concrete work. After its final set the coping was covered with several inches of fine gravel which was kept wet for at least a week.

"The last concrete laid during the season was in November, on Lock No. 21, and Aqueducts Nos. 2 and 3. Portions of these structures were built when the temperature was below freezing. The water was warmed to about 60 or 70° Fahr., by discharging exhaust steam into the tank. Salt was used only in the facing, simply sufficient to make the water taste saline. The maximum amount used on the coldest night when the temperature was about 20° Fahr. was 1½%.

The concrete force on each shift was as follows:

	Men.
Filling and pushing stone car	10
Filling and pushing gravel car	8
Measuring cement	3
Measuring water and cleaning bucket	2
Dumping bucket on top platform	2
Operating mixer	2
Loading concrete cars	1
Pushing and dumping cars on forms	3
Switchmen on forms	2
Spreading concrete in forms	12

	Men
Tamping concrete in forms	16
Mixing facing	3
Water-boys	2
Total laborers	66
Operating hoists	2
Finishing coping	2
Fireman	1
Sub-overseers	2
Overseer	1
Total force	74

"The cost of material and labor at Lock No. 15 (10 ft. lift), which contains 2,558 cu. yds. of concrete, was as follows:

Materials:	Per cu. yd.
0.56 bbl. Port. cement (0.96 per cu. yd)	$1.42
0.64 " Utica " (1.58 " " ")	.30
0.58 cu.. yd. stone	1.15
0.60 " " gravel	.52
14 ft. B. M. lumber* at $15 per M	.21
0.6 lb. spikes	.01
Coal (10 tons in all, at $1.70)	.01
0.35 gal. kerosene	.03
Total materials	$3.65
Labor:	
Erecting forms ($7 per M)	.45
Removing " ($2 per M.)	.13
Erecting and removing mixer ($161)	.06
Loading and unloading materials at yards and lock sites	.23
Track laying ($86)	.03
Train service (narrow gage road)	.09
Delivering materials to mixer	.28
Mixing concrete	.11
Depositing "	.21
Tamping "	.21

* The lumber was used nearly five times, which accounts for its low cost per cu. yd.

	Per cu. yd.
Mix., dep. and tamping, 69 cu. yds. face mortar ($160)	$0.23
General construction ($553)	.22
Total labor	$2.25

"There were 1,430 cu. yds. of Portland cement concrete, 69 cu. yds. of Portland cement mortar facing, and 1,059 cu. yds. of Utica cement concrete. The Portland concrete cost $6.43 per cu. yd.; the Utica concrete, $4.77 per cu. yd. The following is the cost of labor on Lock No. 20 (11 ft. lift.; 2,750 cu. yds.):

	Per cu. yd.
Erecting forms ($7 per M.)	$ .434
Removing " ($1.70 per M.)	.113
Erecting and removing mixer ($151)	.058
Loading and unloading at yards, lock sites, etc.	.614
Tracks	.024
Train service (narrow gage)	.016
Pumping	.114
Delivering material to mixer	.288
Mixing concrete	.134
Depositing concrete	.205
Tamping concrete	.192
Mix., dep. and tamping, 85 cu. yds. face mortar	.071
General construction	.246
Total	$2.509

Labor Cost of Retaining Walls.—In canal excavation, in subway work in cities, and the like, it is often necessary to dig trenches and build retaining walls in the trenches before excavating the core of earth between the walls. The following example of this class of work is taken from some records that I have: A Smith mixer was used, the concrete being delivered where wanted by a Lambert cableway of 400 ft. span. The broken stone and sand were delivered near the work in hopper-bottom cars which were dumped through a trestle onto a plank floor. Men loaded the material into one-horse dump carts which hauled it 900 ft. to the mixer platform. This platform was 24 × 24 ft. square, and 5 ft. high, with a planked approach 40 ft. long and contained 7,500 ft. B. M. The stone and sand were dumped at the

mouth of the mixer and shoveled in by 4 men. Eight men, working in pairs, loaded the broken stone into the carts, and 2 men loaded the sand. Each cart was loaded with about 70 shovelfuls of stone on top of which 35 shovelfuls of sand were thrown. It took 3 to 5 mins. to load on the stone and 1 min. to load the sand. The carts traveled very slowly, about 150 ft. a minute—in fact, all the men on the job, including the cart drivers, were slow. After mixing, the concrete was dumped into iron buckets holding 14 cu. ft. water measure, making about ½ cu, yd. in a batch. The buckets were hooked on to the cableway and conveyed where wanted in the wall. Steam for running the mixer was taken from the same boiler that supplied the cableway engine. The average output of this plant was 100 cu. yds. of concrete per 10-hr. day, although on many days the output was 125 cu. yds., or 250 batches. The cost of mixing and placing was as follows, on a basis of 100 cu. yds. per day:

	Per day.	Per cu. yd.
8 men loading stone into carts	$12.00	$ .12
2 " " sand " "	3.00	.03
1 cart hauling cement	3.00	.03
8 carts " stone and sand	24.00	.24
4 men loading mixer	6.00	.06
1 man dumping mixer	1.50	.01
2 men handling buckets at mixer	3.00	.03
6 " dumping buckets and ramming	9.00	.09
12 " making forms at $2.50	30.00	.30
1 cable engineman	3.00	.03
1 fireman	2.00	.02
1 foreman	6.00	.06
1 water-boy	1.00	.01
1 ton coal for cableway and mixer	4.00	.04
Total	$107.50	$1.07

In addition to this cost of $1.07 per cu. yd. there was the cost of moving the whole plant for every 350 ft. of wall. This required 2 days, at a cost of $100, and as there were about 1,000 cu. yds. of concrete in 350 ft. of wall 16 ft. high, the cost of moving the plant was 10 cts. per cu. yd. of concrete, bringing the total cost of mixing and placing up to 87 cts. per cu. yd. As above stated, the whole gang was slow.

The labor cost of making the forms was high, for such simple and heavy work, costing $10 per M. of lumber placed each day. The forms were 2-in. sheeting plank held by 4 × 6-in. upright studs 2½ ft. apart, which were braced against the sides of the trench. The face of the forms was dressed lumber and all cracks were carefully puttied and sandpapered.

The above costs relate only to the massive part of the wall and not the cost of putting in the facing mortar, which was excessively high. The face mortar was 2 ins. thick, and about 3½ cu. yds. of it were placed each day with a force of 8 men! Two of these men mixed the mortar, 2 men wheeled it in barrows to the wall, 2 men lowered it in buckets, and 2 men put it in place on the face of the wall. If we distribute this labor cost on the face mortar over the 100 cu. yds. of concrete laid each day, we have another 12 cts. per cu. yd.; but a better way is to regard this work as a separate item, and estimate it as square feet of facing work. In that case these 8 men did 500 sq. ft. of facing work per day at a cost of nearly 2½ cts. per sq. ft. for labor.

The building of a wall similar to the one just described was done by another gang as follows: The stone and sand were delivered in flat cars provided with side boards. In a stone car 5 men were kept busy shoveling stone into iron dump buckets having a capacity of 20 cu. ft. water measure. Each bucket was filled about two-thirds full of stone, then it was picked up by a derrick and swung over to the next car which contained sand, where two men filled the remaining third of the bucket with sand. The bucket was then lifted and swung by the derrick over to the platform of the mixer where it was dumped and its contents shoveled by four men into the mixer, cement being added by these men. The mixer was dumped by two men, loading iron buckets holding about ½ cu. yd. of concrete each, which was the size of each batch. A second derrick picked up the concrete bucket and swung it over to a platform where it was dumped by one man; then ten men loaded the concrete into wheelbarrows and wheeled it along a runway to the wall. One man assisted each barrow in dumping into a hopper on the top of a sheet-iron pipe which delivered the concrete. The two derricks were stiff-leg derricks with 40-ft. booms, provided with bull-wheels, and operated by double cylinder (7 × 10-

in.) engines of 18HP. each. About 1 ton of coal was burned daily under the boiler supplying steam to these two hoisting engines. The output of this plant was 200 batches or 100 cu. yds. of concrete per 10-hr. day, when materials were promptly supplied by the railroad; but delays in delivering cars ran the average output down to 80 cu. yds. per day.

On the basis of 100 cu. yds. daily output, the cost of mixing and placing the concrete was as follows:

	Per day.	Per cu. yd.
5 men loading stone	$7.50	$ .07½
2 " " sand	3.00	.03
4 " charging mixer	6.00	.06
2 " loading concrete into buckets	3.00	.03
1 " dumping " from "	1.50	.01½
10 " loading and wheeling concrete	15.00	.15
1 " dumping wheelbarrows	1.50	.01½
3 " spreading and ramming	4.50	.04½
2 enginemen	5.00	.05
1 fireman	2.00	.02
1 water-boy	1.00	.01
1 foreman	6.00	.06
10 men making forms	25.00	.25
1 ton coal	4.00	.04
Total	$85.00	$ .85

In addition there were 8 men engaged in mixing and placing the 2-in. facing of mortar as stated above.

Cost of Retaining Walls, Chicago Drainage Canal.—Mr. James W. Beardsley gives the following data on 20,000 lin. ft. of concrete wall, built by contract. The work was let in two sections, Secs. 14 and 15, which will be considered separately. In both cases a 1 : 1½ : 4 natural cement concrete was used, and it was faced with 1 : 3 Portland mortar 3 ins. thick, also coped with the same 3 ins. thick. The average height of the wall was 10 ft. on Sec. 14, and 22 ft. on Sec. 15, the thickness at the base being half the height.

On Sec. 14, the stone for the concrete was obtained from the spoil bank of the canal, loaded into wheelbarrows and wheeled about 100 ft. to the crusher; some was hauled in

wagons. An Austin jaw crusher was used, and it discharged the stone into bins from which it was fed into a Sooysmith mixer. The crusher and the mixer were mounted on a flat car. Bucket elevators were used to raise the stone, sand and cement from their bins to the mixer; the buckets were made of such size as to give the proper proportions of ingredients, as they all traveled at the same speed. Only two laborers were required to look after the elevators. The sand and cement were hauled by teams and dumped into the receiving bins. There were 23,568 cu. yds. on Sec. 14, and the cost was as follows:

	Typical force.	Wages per 10 hrs.	Cost per cu. yd.
General force:			
Superintendent	1.0	$5.00	$0.026
Blacksmith	1.1	2.75	0.016
Timekeeper	0.5	2.50	0.007
Watchman	0.6	2.00	0.007
Waterboys	3.9	1.00	0.022
Wall force:			
Foreman	0.9	2.50	0.013
Laborers	8.6	1.50	0.073
Tampers	2.3	1.75	0.022
Mixer force:			
Foreman	1.2	2.50	0.017
Enginemen	1.8	2.50	0.025
Laborers	6.7	1.50	0.057
Pump runner	1.0	2.00	0.010
Mixing machines	1.7	1.25	0.012
Timber force:			
Foreman	0.6	2.50	0.008
Carpenters	4.7	2.50	0.057
Laborers	1.2	1.50	0.010
Helpers	5.3	2.50	0.075
Hauling force:			
Laborers	2.6	1.75	0.026
Teams	6.3	3.25	0.116

Crushing force:	Typical force.	Wages per 10 hrs.	Cost per cu. yd.
Foreman	0.5	$2.50	$0.007
Engineman	1.7	2.50	0.023
Laborers	3.5	1.50	0.032
Austin crushers	1.7	1.20	0.011
Loading stone:			
Foremen	1.7	2.50	0.023
Laborers	32.9	1.50	0.280
Total for crushing, mixing and placing			$0.975

The daily costs charged to the mixers and crushers include the cost of coal, at $2 a ton, and the cost of oil.

The gang "loading stone" apparently did a good deal of sledging of large stones, and they also wheeled a large part of it in barrows to the crusher.

The plant cost $9,600, distributed as follows:

2 jaw crushers	$3,000
2 mixers	3,000
Track	1,260
Lumber	500
Pipe	840
Sheds	400
Pumps	600
Total	$9,600

If this first cost of the plant were distributed over the 23,568 cu. yds. of concrete it would amount to 41 cts. per cu. yd.

The cost of the concrete was as follows:

	Per cu. yd.
Utica cement, at $0.65 per bbl	$0.863
Portland cement, at $2.25 per bbl.	0.305
Sand, at $1.35 per cu. yd.	0.465
Stone and labor, as above given	0.975
Total	$2.608
First cost of plant	$0.407

On Sec. 15 the conditions were much the same as on Sec. 14, just described, except that the limestone was quarried from the bed of the canal, and was crushed in a stationary crusher, No. 7 Gates. The stone was hauled 1,000 ft. to the crusher on cars drawn by a cable from a hoisting engine. The output of this crusher averaged 210 cu. yds. per day of 10 hrs. The crushed stone was hauled in dump cars, drawn by a locomotive, to the mixers. Spiral screw mixers mounted on flat cars were used, and they delivered the concrete to belt conveyors which delivered the concrete into the forms.

The forms on Sec. 15 (and on Sec. 14 as well) consisted of upright posts set 8 ft. apart and 9 ins. in front of the wall, held at the toe by iron dowels driven into holes in the rock, and held to the rear posts by tie rods. The plank sheeting was made up in panels 2 ft. wide and 16 ft. long, and was held up temporarily by loose rings which passed around the posts which were gripped by the friction of the rings. These panels were brought to proper line and held in place by wooden wedges. After the concrete had set 24 hrs. the wedges were struck, the panels removed and scraped clean ready to be used again.

The cost of quarrying and crushing the stone, and mixing the concrete on Sec. 15 was as follows:

	Typical force.	Wages per 10 hrs.	Cost per cu. yd.
General force:			
Superintendent	1.0	$5.00	$0.024
Blacksmith	0.9	2.75	0.011
Teams	1.7	3.00	0.025
Waterboy	4.5	1.00	0.022
Wall force:			
Foreman	1.1	2.50	0.010
Laborers	14.4	1.50	0.105
Tampers	0.1	1.75	0.001
Mixer force:			
Foreman	2.1	2.50	0.026
Enginemen	2.1	2.50	0.022
Laborers	23.1	1.50	0.180
Mixing machines	2.1	1.25	0.022

Timber force:	Typical force.	Wages per 10 hrs.	Cost per cu. yd.
Carpenters	0.3	3.00	0.013
Laborers	0.7	1.50	0.005
Helpers	10.2	2.50	0.125
Hauling force:			
Foreman	0.7	2.50	0.009
Enginemen	1.4	2.50	0.019
Fireman	0.4	1.75	0.003
Brakeman	2.2	2.00	0.018
Teams	0.4	3.25	0.007
Laborers	1.5	1.50	0.010
Locomotives	1.4	2.25	0.015
Crushing force:			
Foreman	1.0	2.50	0.014
Enginemen	1.0	2.50	0.014
Laborers	11.1	1.50	0.081
Firemen	1.0	1.75	0.008
Gyratory crusher	1.0	2.25	0.011
Quarry force:			
Foreman	1.2	2.50	0.012
Laborers	19.0	1.50	0.140
Drillers	1.8	2.00	0.017
Drill helpers	1.8	1.50	0.013
Machine drills	1.8	1.25	0.011
Total			$0.993

The first cost of the plant for this work on Sec. 15 was $25,420, distributed as follows:

1 crusher, No. 7 Gates	$12,000
Use of locomotive	2,200
Cars and track	5,300
3 mixers	3,000
Lumber	1,200
Pipe	720
Small tools	1,000
Total	$25,420

This $25,420 distributed over the 44,811 cu. yds. of concrete amounts to 57 cts. per cu. yd.

It will be noted that 2 mixers were kept busy. Their average output was 100 cu. yds. each per day, which is the same as for the mixers on Sec. 14.

The total cost of concrete on Sec. 15 was as follows:

	Per cu. yd.
Labor quarrying, crushing and mixing	$0.991
Explosives	0.083
Utica cement, at $0.60 per bbl.	0.930
Portland cement, at $2.25 per bbl.	0.180
Sand, at $1.35 per cu. yd.	0.476
Total	$2.660
First cost of plant	$0.567

It is not strictly correct to charge the full first cost of the plant to the work as it possessed considerable salvage value at the end.

For the purpose of comparing Secs. 14 and 15 the following summary is given of the cost per cubic yard of concrete:

	Sec. 14.	Sec. 15.
General force	$0.078	$0.082
Wall force	0.108	0.116
Mixing force	0.121	0.250
Timbering force	0.150	0.140
Hauling force	0.142	0.081
Crushing force	0.073	0.128
Quarry force	0.303	0.275
Cement, natural	0.863	0.930
Cement, Portland	0.305	0.180
Sand	0.465	0.476
Plant (full cost)	0.407	0.567
Total	$3.015	$3.225

It should be remembered that on Sec. 14 there was no drilling and blasting of the rock, but that the "quarry force" not only loaded but hauled the stone to the crusher.

The cost of mixing on Sec. 15 is higher than on Sec. 14 because the materials were dumped on platforms and shoveled into the mixer, instead of being discharged from bins into the mixer as on Sec. 14.

Cost of a Retaining Wall.—For building a retaining wall 7 ft. high, forms were made and placed by a carpenter and helper at $8 per M, wages being 35 cts. and 20 cts. an hour, respectively. Concrete materials were dumped from wagons alongside the mixing board. Ramming was unusually thorough. Foreman expense was high, due to small number in gang; 2 cu. yds. were laid per hour by the gang.

	Per day	Per cu. yd.
7 mixers, 15 cts. per hr.	$10.50	$0.53
2 rammers, " "	3.00	0.15
1 foreman, 30 cts. per hr., and 1 water-boy, 5 cts.	3.50	0.17
Total labor	$17.00	$0.85

The total cost was as follows per cubic yard:

	Per cu. yd.
0.8 bbls. Portland cement, at $2	$1.60
Sand	0.30
Gravel	0.70
Labor mixing and placing	0.85
Lumber for forms, at $16 per M	0.56
Labor on " " $8 "	0.28
Total, per cu. yd.	$4.29

The sheathing plank for the forms was 2-in. hemlock.

Cost of Abutments and Piers, Lonesome Valley Viaduct.—Mr. Gustave R. Tuska gives the following on the concrete substructure of the Lonesome Valley Viaduct, near Knoxville, Tenn. There were two U-shaped abutments and 36 concrete piers made of a light limestone that deteriorates rapidly when used for masonry. Derricks were not needed as would have been the case with masonry piers, and colored labor at $1 for 11 hrs. could be used. The piers were made 4 ft. square on top, from 5 to 16 ft. high, and with a batter of 1 in. to the foot. The abutments average 26 ft. high, 26 ft. long on the face, with wing walls 27 ft. long; the

wall at the bridge seat is 5 ft. thick, and the wing walls are 3½ ft. wide on top. Batters are 1 in. to the foot.

The forms were made of 2-in. tongued and grooved plank, braced by posts of 2 × 10-in. plank placed 3 ft. c. to c. for the abutments, and at each corner for the piers. At the corners one side was dapped into the other, so as to prevent leakage of cement. The posts were braced by batter posts from the earth. For the piers a square frame was dropped over the forms and spiked to the posts. The abutment forms were built up as the concreting progressed. The north abutment forms were made in sections 6 ft. high, held by ¾-in. bolts buried in the concrete. The lower sections were removed and used again on the upper part of the work, thus saving plank. The inside of forms was painted with a thin coat of crude black oil. The same form was used for several piers.

The concrete was 1:2:5, the barrel being the unit of measure, making about ¾ cu. yd. of concrete per batch. The mortar was mixed with hoes, but shovels were used to mix in the stone. By passing the blade of a shovel between the form and the concrete, the stone was forced back and a smooth mortar face was secured. Rammers weighing 30 to 40 lbs. were used for tamping. Two days after the completion of a pier the forms were removed. The concrete was protected from the sun by twigs, and was watered twice a day for a week. It was found by actual measurement that 1 cu. yd. of concrete (1:2:5), the ingredients being measured in barrels, consisted of 1¼ bbls. of Atlas cement, 10 cu. ft. of sand, and 26½ cu. ft. of stone. The total amount of concrete was 926 cu. yds. of which two-thirds was in the two abutments. The work was done (in 1894) by contract, for $7 per cu. yd., cement costing $2.80 per bbl., sand 30 cts. per cu. yd., and wages $1 a day. A slight profit was made at this price. A gang of 15 men and a foreman would mix and lay about 40 cu. yds. in 11 hrs. when not delayed by lack of materials. The cost of making the concrete, with wages at $1 a day, was:

	Cts. per cu. yd.
1 man filling sand barrels and handling water......	2.7
2 men " rock "	5.4
4 " mixing sand and cement....................	10.6
4 " " stone and mortar....................	10.6

	Cts. per cu. yd.
2 men wheeling concrete	5.3
1 man spreading concrete in place	2.7
1 " tamping	2.7
Total labor	40.0
1 foreman at $2	5.0
Total exclusive of forms	45.0

If wages had been $1.50 a day instead of $1, the labor cost would have been 68 cts. per cu. yd.

Cost of Bridge Abutments.—Mr. W. A. Rogers gives the following data relative to the construction of bridge abutments on the C. M. & St. P. Ry.: The work consisted in building 20 abutments for 10 four-track plate girder bridges over street crossings in Chicago. The work was done between May 1 and Oct. 1, 1898, in which time 8,400 cu. yds. of concrete were placed, all the work being done by company labor. The forms were made of 2-in. plank and 6 × 6-in. posts bolted together at the top and bottom with ¾-in. rods. The lumber was used over and over again. When the dressed plank became too poor for the face it was used for the back. The concrete was 1 Portland cement, 3 gravel and 4 to 4½ limestone (crusher run up to 3-in. size). A mortar face 1½ ins. thick was built up with the rest of the concrete. The concrete was made quite wet, and each man ramming averaged 18 cu. yds. a day rammed. The concrete was mixed by a machine of the Ransome type, operated by a 12-HP. portable gasoline engine. The load was very light for the engine, and 8 HP. would have been sufficient. The engine made 235 revolutions per minute, and the pulley wheels were proportioned so that the mixer made 12 revs. per min. One gallon of gasoline was used per hour, and the mixing was carried on day and night so as not to give the concrete time to set. The time required for each batch was 2 to 3 mins., and about ½ cu. yd. of concrete was delivered per batch. The average output was 70 cu. yds. per 10-hr. shift, with a crew of 28 men; but as high as 96 cu. yds. were mixed in 10 hrs. The concrete was far superior to hand mixed concrete. The water for the concrete was measured in an upright tank and discharged by a pipe into the mixer. The sand and stone were delivered to the mixer in wheel-

barrows, and the concrete was taken away in wheelbarrows, No derricks were used at all. Each wheelbarrow of concrete was raised by a rope passing over a pulley at the top of a gallows frame; one horse and a driver serving for this raising. A small gasoline hoisting engine would have been more satisfactory than the horse which was worked to its full capacity. After the barrows were raised (12 ft.), they were wheeled to the abutment forms and dumped. The empty wheelbarrows were lowered by hand, by means of a rope passing over a sheave and provided with a counter-weight to check the descent of the barrow. The cost of the concrete (built by company labor) was as follows:

	Per cu. yd.
Cement, gravel and stone delivered..............	$3.28
Material in forms (used many times).............	.11
Carpenters building and taking down forms......	.34
Labor	1.18
Total per cu. yd...........................	$4.91

The labor cost includes moving the plant from one bridge to the next, building runways, gasoline for engine, oil for lights at night, and unloading materials as well as mixing, delivering and ramming the concrete. Wages were $1.75 per 10-hr. day for laborers and $2.50 for carpenters.

Cost of 6 Arch Culverts and 6 Bridge Abutments, N. C. & St. L. Ry.—Mr. H. M. Jones is authority for the following data: An 18-ft. full-centered arch culvert was built by contract on the N. C. & St. L. Ry., near Paris, Tenn. The culvert was built under a trestle 65 ft. high, before filling in the trestle. The railway company built a pile foundation to support a concrete foundation 2 ft. thick, and a concrete paving 20 ins. thick. The contractors then built the culvert which has a barrel 140 ft. long. No expansion joints were provided, which was a mistake for cracks have developed about 50 ft. apart. The contractors were given a large quantity of quarry spalls which they crushed in part by hand, much of it being too large for the concrete. The stone was shipped in drop-bottom cars and dumped into bins built on the ground under the trestle. The sand was shipped in ordinary coal cars, and dumped or shoveled into bins. The mixing boards were placed on the surface of the ground,

and wheelbarrow runways were built up as the work progressed. The cost of the 1,900 cu. yds. of concrete in the culverts was as follows per cu. yd:

1.01 bbls. Portland Cement	$2.26
0.56 cu. yds. of sand, at 60 cts	.32
Loading and breaking stone	.25
Lumber, centers, cement house and hardware	.64
Hauling materials	.04
Mixing ane placing concrete	1.17
Carpenter work	.19
Foreman (100 days at $2.50)	.13
Superintendent (100 days at $5.50)	.29
	$5.29

It will be seen that only 19 cu. yds. of concrete were placed per day with a gang that appears to have numbered about 21 laborers, who were negroes receiving about $1.10 per day. This was the first work of its kind that the contractors had done. It will be noticed that the cost of 42 cts. per cu. yd. for superintendence and foremanship was unnecessarily high.

The work in Tables XV. and XVI. was "company work" done by negro labor under company foremen.

TABLE XV.

Cost of Six Concrete Culverts on the N. C. & St. L. Ry.

No. of culvert	1	2	3	4	5	6
Span of culvert	5 ft.	7.66 ft.	10 ft.	12 ft.	12 ft.	16 ft.
Cu. yds. of concrete	210	199	354	292	406	986
Ratio of cement to stone	1:5.5	1:6.5	1:5.8	1:5.8	1:6.1	1:6.5
Increase of concrete over stone	16.0%	9.9%	6.3%	12.3%	8.3%	5.3%
Bbls. cement per cu. yd	1.02	0.90	1.06	1.01	1.00	1.09
Cu. yds. sand per cu. yd	0.43	0.49	0.44	0.46	0.46	0.47
Cu. yds. stone per cu. yd	0.86	0.90	0.95	0.89	0.94	0.94
Total days labor (incl. foremen and supt.)	702	607	784	726	768	1,994
Av. wages per day (incl. foremen and supt)	$1.61	$1.33	$1.59	$1.19	$1.47	$1.46
Cost per cu. yd.:						
Cement	2.18	1.94	2.27	1.82	2.11	2.01
Sand	0.17	0.20	0.18	0.18	0.19	0.14
Stone	0.52	0.52	0.47	0.54	0.47	0.58
Lumber	0.88	0.43	0.48	0.43	0.31	0.57
Unload. materials	0.23	0.17	0.18	0.18	0.16	....
Building forms	1.07	0.83	0.62	0.47	0.72	0.41
Mixing & placing	1.59	1.74	1.69	1.35	1.23	1.26
Total per cu. yd	$6.65	$5.30	$5.89	$4.97	$5.19	$4.97

Note:—All these arches were built under existing trestles, and in all cases, except No. 2, bins were built on the ground under the trestle and the materials were dumped from cars into the bins, loaded and delivered from the bins in wheelbarrows to the mixing boards, and from the mixing boards carried in wheelbarrows to place. Negro laborers were used in all cases, except No. 5, and were paid 90 cts. a day and their board, which cost an additional 20 cts.; they worked under white foremen who received $2.50 to $3 a day and board. In culvert No. 5, white laborers, at $1.25 without board, were used. There were two carpenters at $2 a day and one foreman at $2.50 on this gang, making the average wage $1.47 each for all engaged. The men were all green hands, in consequence of which the labor on the forms in particular was excessively high. The high rate of daily wages on culverts Nos. 1 and 3 was due to the use of some carpenters along with the laborers in mixing concrete. The high cost of mixing concrete on culvert No. 2 was due to the rehandling of the materials which were not dumped into bins but onto the concrete floor of the culvert and then wheeled out and stacked to one side. The cost of excavating and backfilling at the site of each culvert is not included in the table, but it ranged from 70 cts. to $2 per cu. yd. of concrete.

TABLE XVI.

Cost of Concrete Abutment, Retaining Walls and Foundations.

No. of structure	7	8	9	10	11	12
Cu. yds, of concrete	310	99	282	78	71	72
Ratio of cement to stone	1:5.7	1:6.3	1:5.9	1:6.6	1:5.7	......
Increase of concrete over stone	6.2%	10.0%	12.8%	4.0%	10.9%	......
Bbls. cement per cu. yd	1.09	0.95	0.99	0.96	1.03	1.39
Cu. yds. sand per cu. yd	0.47	0.45	0.44	0.51	0.45	0.56
Cu. yds. stone per cu. yd	0.94	0.91	0.90	0.96	0.90	1.09
Total days labor (incl. foremen)	573	226	599	128	131	224
Av. wages per day (incl. foremen)	$1.43	$1.88	$1.46	$1.69	$2.05	$1.55
Cost per cu. yd.;						
Cement	$2.32	$1.66	$1.98	$2.07	$2.19	$2.95
Sand	0.19	0.18	0.18	0.21	0.18	0.17
Stone	0.52	0.18	0.22	0.48	0.18	0.65
Lumber	0.56	0.09	0.26	0.26	0.51	0.34
Building forms	0.35	0.40	1.09	....	....	....
Mixing & placing	1.94	3.38	1.36	2.21	1.74	2.59
Total	$5.88	$5.91	$5.09	$5.23	$4.80	$6.70

Note:—Structure No. 7 consists of two abutments to carry a 24-ft. span bridge made of I-beams. Bins to hold stone and sand were built on the railway embankment. At the head of the bin a part of the bank was dug away under the track, and long stringers put in to carry the track. The rock was dumped from the car into this opening and shoveled into the bin. The forms for the concrete were, of course, simpler than for the arches in Table XV.; hence the labor on them cost less.

Structure No. 8 consists of concrete side walls to support a cedar cover, forming a culvert. Slag was used instead of crushed stone in this structure as well as in Nos. 9 and 11.

Structure No. 9 is a retaining wall. There was much handling of materials due to lack of room for storage near the work. Old material was used for the forms.

Structures Nos. 10 to 12 are foundations for track scales. It is not clear why the labor cost of this work was so very high.

Cost of an Arch Culvert.—In Engineering Record, Apr. 12, 1902, the following is given:

The cost of a concrete arch culvert, 26 ft. span, 62 ft. barrel (exclusive of excavation), with wing walls and parapet, built near Pittsburg in 1901, was as follows, the concrete being 1 to 8 and 1 to 10, hand mixed:

	Per cu. yd.
0.96 bbl. cement, at $1.60	$1.535
1.03 tons coarse gravel, at $0.19	0.195
0.40 " fine " " 0.21	0.085
0.32 " sand " 0.36	0.115
Tools, etc.	0.078
Lumber for forms and centers	0.430
Carpenter work on forms (23 cts. hr.)	0.280
" " " platforms and buildings	0.050
Preparing site and cleaning up	0.210
Changing trestle	0.085
Handling materials	0.037
Mixing and laying, av. 15½ cts. per hr.	1.440
Total per cu. yd.	$4.540

Wages per hour were: General foreman, 40 cts.; foreman, 25 cts.; carpenters, 22½ to 25 cts.; laborers, 15 cts. The

finished structure contained 1,493 cu. yds. total cost, being $7,243, including $463 for excavation. The work was done for a railway apparently by company forces.

Concrete Arch Viaduct, S. P., L. A. & S. L. R. R.—In Engineering News, Oct. 22, 1903, Mr. A. C. Ostrom gives the following facts about an eight-arch viaduct crossing the Santa Ana River on the San Pedro, Los Angeles & Salt Lake R. R. The viaduct is 984 ft. long, 17 ft. wide, 55 ft. high (averaged), and contains 14,000 cu. yds. of concrete without any steel reinforcement. Each arch has a radius of 43½ ft., a rise of 37 ft., and a thickness of 42 ins. at the crown. The arch ring projects 6 ins. beyond the face of the spandrel walls. The piers have a footing 16 × 28 ft. resting on granite, and narrow by steps to 9 × 21. They are penetrated vertically by two wells 2½ × 5 ft., thus saving concrete and providing drainage by weep holes below and horizontal tunnels at the top of the arch haunch. There are two sets of spandrel walls connected by cross walls, covered by a 10-in. concrete floor which sustains the 3½ ft. of ballast. Cement and gravel in the ratio 1 to 11 were used for the foundations and spandrel walls. The arch rings were made of 1:2:4½ stone concrete. The gravel was washed by means of a sluice passing through a box where the coarse gravel and clean sand settled. Three Ransome mixers were operated by a 25-HP. engine. The arch centers were supported on four bents of four piles per bent driven to bed rock. These were capped by 12 × 12-in. caps. The thrust from the segments was conveyed by radial 8 × 8-in. struts to horizontal chords which were upheld by wedges placed on 12 × 12-in. stringers that rested upon the caps.

Cost of a Highway Arch Bridge.—In Engineering News, Aug. 27, 1903, Mr. William B. Barber gives the following data: This highway bridge crosses San Leandro Creek, Cal. It has a macadam roadway 41 ft. wide, and two 8-ft. cement walks. The span is 81¼ ft., the rise is 26 ft., and the thickness is 3 ft. The footings have at the crown a width of 30 ft. on each side and extend 5 ft. below the bed of the creek, resting upon a bed of clay without any pile supports. There were 90,000 ft. B. M. of lumber in the centers. The concrete was a 1:2:7 of broken stone. The bridge contains 3,384 cu. yds., and was built at a contract price of $25,840 by the E. B. & A. L. Stone Co., of Oakland, Cal.

Cost of a Reinforced Arch Highway Bridge.—Mr. P. A. Courtright gives the following on the cost of mixing and placing concrete in a concrete-steel bridge having 7 arches, each of 54 ft. span and 8 ft. rise, at Plainwell, Mich., in 1903, as follows:

	Total per day.	Total per cu. yd.
13 men, at $1.80	$23.40	$0.78
Engine and mixer	5.00	0.17
1 team	3 00	0.10
1 foreman	3.00	0.10
Total labor for 30 cu. yds.	$34.40	$1 15
0.9 cu. yd. gravel, at $0.50		$0 45
0.65 bbl. cement, at $2.00		1.30
Total, per cu. yd.		$2.90

The concrete yardage was as follows.

570 cu. yds. of 1:8 gravel concrete in foundations.
770 " " " 1:6 " " " arches.
150 " " " 1:6 " " " walls.

One sack of cement was considered to be 1 cu. ft. The bridge had an 18-ft. roadway and a 5-ft. side wall, a total length of 446 ft., and the estimate of its cost at contract prices was:

1,490 cu. yds. concrete, at $7.00	$10,430
1,200 " " earth fill, at $0.30	360
36,000 lbs. of steel, at $0.05	1,800
2,800 ft. of piles in foundations, at $0.20	560
2,230 sq. ft. of cement walk, at $0.10	223
Total	$13,373
Excavating, pumping, cofferdams, and centers, $791 per arch	5,537
Grand total	$18,910

I would say that the above estimate appears to be too high on the concrete item, and too low on nearly every other item, except perhaps the last.

The method of making the concrete was as follows: The gravel, which had 32% voids, and contained sufficient sand.

was shoveled into a 1 cu. yd. wagon at the pit, and hauled to a platform at the intake of a McKelvey continuous mixer. Half the cement required for a batch was spread over the load of gravel before dumping the load through the bottom of the wagon; then the rest of the cement was added after dumping. One man shoveled the material over to another man who shoveled it into the mixer. After the material had passed one-third the length of the mixer, water was turned in. The mixer delivered the concrete into wheelbarrows from which it was dumped to place and spread in 3-in. layers. Two men were employed tamping to 1 man shoveling the concrete. The gravel for the arches and walls was screened through a 2-in. mesh screen placed on the wagon while loading at the pit. Regarding the product of the mixer, Mr. Courtright says: "A more complete blending of materials would be difficult to produce." This statement is noteworthy in view of the common prejudice against continuous mixers.

Centers.—The heels were supported on the benches constructed upon each pier and abutment foundation. Each center was supported at the panel joints by twelve temporary piles. These were driven in advance of the foundation work, sawed off, capped with timbers, and used as a working platform.

The centers themselves were made of Georgia pine plank. Each rib section was built up with three planks, two 2 × 12 inch for outside, and one 10 × 2-inch between. These were securely nailed and bolted together, the panels being joined by bolting on two pieces of 2 × 4-inch oak.

The top chord was made of one plank, cut in sections, and rounded to fit the intrados of the arch. The panel joints were supported by 8 × 12-inch timbers, carried on posts resting on 8 × 12-inch timber caps on piles.

Wedges for lowering the centers were used at all bearing points.

Centers were covered with 2 × 12-inch planed pine lagging and made a very rigid and smooth surface for concrete. The minimum of time allowed for the removel of centers after the completion of an arch was 28 days.

The appearance of the arch rings, showing the same divided as by joints between stones, was produced by nailing half round strips on the form, and gives a good struc-

tural effect to the work. The entire structure was built in the forms with the single exception of the fourteen keystones, which, owing to their peculiar design, were cast separate, and set in the form.

Piling.—Each abutment foundation has 31 piles, the piers having 23 each. Piles were oak, elm, beech and hickory, not less than 12 ins., nor more than 16 ins. at the head. They cost, delivered on the ground and sharpened ready for driving, 15 cents per lineal foot. The average number driven per day was 8½.

The character of the soil rendered driving very difficult; a penetration of 2 or 3 ins. when starting a pile was the exception rather than the rule.

Cost of driving:

Engine and driver, per day	$5.00
Engineer	2.50
Fireman	1.80
Four driver men, at $1.80	7.20
Total	$16.50

Conditions for construction were very favorable. The water varied in depth from 3 to 5 ft., with a current of from two to three miles per hour. Under the silt and sand which formed the river bed, gravel was found to depth of about 3 ft.; below this, quicksand, filled with stones of varying sizes, was encountered.

For foundations, piles were driven to an approximate depth of 10 ft. below the bed of the stream. Cofferdams were built, the water pumped out, and the excavation carried down until 1 ft. of gravel was left above the quicksand. The piles were sawed off 1½ ft. above the bottom of the excavation, and the concrete carried up to the spring line of the arches.

Cost of 3 Reinforced Arch Bridges, L. S. & M. S. Ry.—Mr. Samuel Rockwell gives the following as to the size and cost of three concrete-steel railway arch bridges: The bridge arches had a span of 30 ft., a rise of 9 ft., a crown thickness of 33 ins., a thickness at the spring of 6½ ft., and a barrel length of 40, 60 and 160 ft., respectively. The abutments were 8 ft. high and 14 ft. wide at the base. Johnson

corrugated steel bars were used, for reinforcement. The concrete was 1 sand, 3 gravel and sand (50% each) and 6 broken stone, laid wet. In all there were 4,833 cu. yds., including wing walls and parapets. The work was done by company forces at Elkhart, Ind., in 1903. It will be noted that the sand and stone were unusually low in cost.

	Total cost.	Cost per cu. yd.
Cement	$8,860	1.84
Stone	1,789	0.36
Sand and gravel (obtained from foundations)	240	0.05
Drain tile	103	0.02
Steel rods	3,028	0.63
Labor on concrete	8,091	1.68
Engineering and watching	508	0.11
Arch centers and forms	3,529	0.73
Sheet piling and boxing	1,006	0.21
Excavating and pumping	1,620	0.33
Machinery, pipe, fittings, etc.	416	0.08
Temporary buildings, trestles, etc.	752	0.15
Total for 4,833 cu. yds.	$29,942	$6.19

Cost of a Blast Furnace Foundation.—In Trans. Am. Soc. C. E., Vol. XV., 1886, Capt. O. E. Michaelis gives the following data: Concrete foundations were built for the Troy Iron and Steel Co.'s blast furnaces on Breaker Island. The excavation was about 15 ft. deep, and the concrete was carried up 13 ft. above the surface, no forms being used, as an 18-in. wall of masonry was built first and filed behind with concrete. It is stated that the men worked with a will (but it does not appear so), although they were paid only $1 a day, for they expected permanent jobs after the completion of the furnaces. The cost of 9,600 cu. yds. of concrete was as follows:

	Per cu. yd.
0.74 cu. yd. stone, at $1.41	$1.04
0.37 " " gravel, at $0.30	.11
0.13 " " sand, at $0.30	.04
1.23 bbls. Rosendale cement, at $1.00	1.23
Labor unloading stone (wages 10 cts. per hr.)	.13

	Per cu. yd.
Labor drawing cement (20 cts. per bbl.)	.02
" making concrete	.85
Total	$3.42
4 mos. superintendence at $2.50 per mo.	.10
Grand total	$3.52

Example of High Cost of Tamping.—Mr. Herman Conrow is authority for the following data: 1 foreman, 9 men mixing, 1 ramming, averaged 15 cu. yds. a day, or only 1½ cu. yds. per man per day, when laying wet concrete. When laying dry concrete the same gang averaged only 8 cu. yds. a day, there being 4 men ramming. With foreman at $2 and laborers at $1.50 a day, the cost was $2.12 per cu. yd. for labor on the dry concrete as against $1.13 per cu. yd. for the wet concrete. Three turnings of the stone with a wet mortar effected a better mixture than four turnings with a dry mortar. The ramming of the wet concrete cost 10 cts. per cu. yd., whereas the ramming of the dry concrete cost 75 cts. per cu. yd.! I think this is the highest cost on record for ramming. It is evident, however, that the men were under a poor foreman, for an output of only 15 cu. yds. per day with 10 men is very low for ordinary conditions. Moreover, the expensive amount of ramming indicates either poor management or the most foolish inspection requirements.

Cost of Filling Pier Cylinders With Concrete.—In this case the gravel and sand forming the concrete were wheeled in barrows a distance of 100 ft. to the mixing-board at the foot of steel pier cylinders, into which concrete was dumped after raising it 20 ft. in wooden skips. Two cu. yds. concrete laid per hour by the gang.

	Per day.	Per cu. yd.
6 men wheeling materials and mixing, 15 cts. per hour	$9.00	$0.45
2 men dumping skips and ramming, 15 cts. per hr.	3.00	0.15
1 team and driver, at 40 cts. per hr.	4.00	0.20
1 foreman, at 30 cts. per hr.	3.00	0.15
Total	$19.00	$0.95

Had the job been larger, more men would have been employed to reduce the fixed expense of team time, for a team can readily raise 10 cu. yds. an hour, using a mast, or gin-pole, with block and tackle. The foreman worked on the mixing-board himself. The concrete was perfectly mixed. The men worked with great energy.

Cost of Concrete Work on Ry. Culverts.—I have described in Engineering News, May 21, 1903, the construction work on the Wabash Ry., near Pittsburg. An abstract of certain data on arch culvert construction is here given. The cost of form work is not included.

One contractor using a ⅞ cu. yd. cubical mixer averaged 40 cu. yds. of concrete per 10-hour day, at the following cost for labor:

	Per day.	Per cu. yd.
1 foreman	$3.00	$0.08
3 men loading barrows and feeding mixer	4.50	0.11
1 man attending to engine of mixer	2.50	0.06
2 men loading barrows with concrete	3.00	0.08
4 " wheeling concrete barrows, 100-ft. haul	6.00	0.15
4 men ramming concrete	6.00	0.15
4 " wheeling in and bedding large stones in concrete	6.00	0.15
Total	$31.00	$0.78

Assuming ⅓ ton of coal per day at $3 per ton, we have 2 cts. more per cu. yd. for fuel.

The plant was located on a hillside with the crusher bins above the loading floor or platform which extended over the top of the mixer, so that crushed stone could be drawn directly from the chutes of the bins and wheeled to the mixer. The sand was hauled up an incline in one-horse carts and dumped on this floor, and was also wheeled in barrows to the mixer. The proportions of ingredients used were 4 bags of cement, 4 barrows of sand and stone dust, and 7 barrows of crushed stone. The cost of ramming, it will be noted, is much larger than is ordinarily the case. The cost of bedding rubble stones in the concrete was greatly outbalanced by the saving in cement.

Another cubical mixer, not in operation when I visited the work, was so arranged as to dump the mixed concrete directly into wooden skips which were run under the mixer on trucks. There were two skips, each holding 1 cu. yd., and one truck running on light rails. A mule was used to pull the loaded skip on the truck over to a 60-ft. boom derrick operated by an engine. This derrick then picked the skip up, swung it over to the concrete wall where it was dumped.

Another contractor had just installed a small Smith conical concrete mixer. Each charge was a small one—4 barrows of stone, 2 barrows of sand and 2 bags of cement—and the mixer was so designed that a low loading platform could be used which is decidedly advantageous where the stone and sand must be wheeled up onto the loading platform. The cubical mixers have a loading platform 8 to 11 ft. above the ground level. This Smith mixer had its loading floor only 4 ft. above the ground level, but it is only fair to add that the mixer is so arranged as to dump its charge into a sort of sump or hole about 3 ft. deep. Into this sump a derrick delivers iron skips which receive the charge of mixed concrete. These skips or buckets are then swung out and dumped in the work. The cost of operating this mixer was:

	Per day.	Per cu. yd
1 man feeding mixer	$1.50	$0.03
1 man running the mixer engine	2.50	0.05
1 derrick engineman	2.50	0.05
2 tagmen swinging derrick boom and dumping buckets	3.00	0.06
6 barrowmen wheeling stone and sand to mixer	9.00	0.18
2 men tamping concrete	3.00	0.06
1 foreman	3.00	0.06
Total	$24.50	$0.49

The cost of coal was about 3 cts. per cu. yd. of concrete.

The output of this gang was 50 cu. yds. per day of 10 hours.

At another culvert the contractor was mixing concrete by hand and claimed that he was doing the work as cheaply as with a mixer, considering moving of plant and depreciation.

He had 20 men working in two gangs of 10 in a gang, each gang being served by a derrick operated by an engine. The daily output of these 20 men was 60 cu. yds. of concrete rammed in place, at a cost of 50 cts. per cu. yd. for labor, not including foreman and engineman.

Cost of Subaqueous Concrete for a Pier.—The following has been abstracted from Engineering News, Mar. 2, 1905, and relates to the construction of a pier 3,023 ft. long at Superior Entry, Wis. The work was done by day labor for the Government, under the direction of Mr. Clarence Coleman, M. Am. Soc. C. E., U. S. Assistant Engineer.

About 80% of the concrete was deposited in molds under water, according to a plan devised in 1902 by Maj. D. D. Gaillard, Corps of Engineers. The molds consisted of bottomless boxes, built in four pieces, two sides and two end pieces, held together by 1¼-in. turnbuckle tie-rods. Cast-iron weights were attached to the molds to overcome the buoyancy of the timber. The concrete was built in place, in two tiers of blocks, the lower tier resting directly on piles and entirely under water. The upper tier of blocks was almost entirely above water. A pile trestle was built on each side of the proposed pier, and a traveler for raising and lowering the molds, spanned the gap between the two trestles. After the mold for a block of concrete had been placed on the bottom, it was filled with concrete lowered in a bucket with a drop bottom. Twelve of these buckets were used, and were hauled from the mixer on cars to a locomotive crane, which lifted each bucket from the car and lowered it to place. The locomotive crane was elevated on a gantry frame so that a train of cars on the same trestle could pass directly under it without interference. This enabled two of these locomotive cranes to work on the same trestle.

Each concrete bucket was provided with two 12-oz. canvas curtains or covers each 3 × 4 ft., quilted with 110 pieces of 1-16 × 1 × 3-inch sheet-lead. The curtains were fastened, one to each side of the top of the bucket, and were folded over the concrete so as to cover it completely and protect it from wash while being lowered through the water. Occasionally, when an opportunity occurred to allow the top of the concrete in a bucket to be examined after being lowered and raised through 23 ft. of water, the concrete was invariably found in good condition. Discoloration

of the water from cement was seldom noticed during the descent of the bucket. The concrete for this subaqueous work was mixed quite wet.

The pebbles for the concrete were delivered by contract, and were unloaded from the scows by means of a clamshell bucket into a hopper. This hopper fed the pebbles on to an endless belt conveyor which delivered them to a rotary screen. Inside this screen water was discharged under a pressure from a 4-in. pipe, to wash the pebbles. From the screen the pebbles passed through a chute into 4-yd. cars, which were hauled up an incline to a height of 65 ft. by means of a hoisting engine. The cars were dumped automatically, forming a stock pile. Under the stock pile was a double gallery or tunnel, provided with eight chutes through the roof; and from these chutes the cars were loaded and hauled by a hoisting engine up an inclined trestle to the bins above the concrete mixer. A system of electric bell signals was used in handling these cars.

The sand was handled from the stock pile in the same manner. The cement was loaded in bags on a car at the warehouse, hauled to the mixer and elevated by a sprocket-chain elevator.

Chutes from the bins delivered the materials into the concrete mixer which was of the modified cubical type revolving on trunnions about an axial line through diagonal corners of the cube. The mixer possessed the advantage of charging and discharging without stopping. It was driven by a 7 × 10-in. vertical single engine with boiler. The mixer demonstrated its ability to turn out a batch of perfectly mixed concrete every 1⅓ mins. It discharged into a hopper, provided with a cut-off chute, which discharged into the concrete buckets on the cars. Four buckets of concrete were hauled in a train by a locomotive to their destination. There were two locomotives and 23 cars.

In the operation of this plant 55 men were employed, 43 being engaged on actual concrete work and 12 building molds and appliances for future work. The work was done by day labor for the Government, and the cost of operation was as follows for one typical week when, in 6 days of 8 hours each, the output was 1,383 cu. yds., or an average of 230 cu. yds. per day. The output on one day was considerably below the average on account of an accident to plant, but this may be considered as typical.

	Per cu. yd.
Pebbles from stock pile to mixer:	
4 laborers, at $2	$0.0348
1 engineman, at $3	0.0131
Coal, oil and waste, at $1.03	0.0043
Sand from stock pile to mixer:	
5 laborers, at $2	0.0434
1 engineman, at $2.50	0.0109
Coal, oil and waste, at $0.82	0.0035
Cement from warehouse to mixer:	
5 laborers, at $2	0.0434
Mixing concrete:	
1 engineman, at $2.50	0.0109
1 mechanic, at $2.50	0.0108
Coal, oil and waste, at $1.29	0.0056
Transporting concrete:	
4 laborers, at $2	0.0348
1 engineman, at $3	0.0130
Coal, oil and waste, at $0.66	0.0028
Depositing concrete in molds:	
4 laborers, at $2	0.0348
1 engineman, at $3	0.0130
1 rigger, at $3	0.0130
Coal, oil and waste, at $1.18	0.0051
Assembling, transporting, setting and removing molds:	
4 laborers, at $2	0.0347
1 engineman, at $3.25	0.0141
1 carpenter, at $3	0.0130
1 mechanic, at $2.50	0.0109
Coal, oil and waste, at $1.39	0.0060
Care of tracks:	
1 laborer, at $2	0.0086
1 mechanic, at $2.50	0.0109
Supplying coal:	
3 laborers, at $2	0.0260

Blacksmith work:	Per cu. yd.
1 laborer, at $2	$0.0086
1 blacksmith, at $3.25	0.0141
Water boy, at $0.75	0.0032
Total per cu. yd.	$.4473
Add 75% of the cost of administration	0.1388
Total labor per cu. yd.	$.5861

The total cost of each cubic yard of concrete in place is estimated to be as follows:

	Per cu. yd.
Ten-elevenths cu. yd. pebbles, at $1.085	$0.9864
Ten-twenty-seconds cu. yd. sand, at $0.00	0.0000
1.26 bbls. cement, at $1.77	2.2302
Labor, as above given	0.5861
Cost of plant distributed over total yardage	0.8400
Total	$4.6427

It will be noticed that the sand cost nothing, as it was dredged from the trench in which the pier was built, and paid for as dredging. The cost of the plant was distributed over the South Pier work and over the proposed North Pier work, on the basis of cnly 20% salvage value after the completion of both piers. It is said, however, that 80% is too high an allowance for the probable depreciation.

The cost of the trestles was included in the cost of the plant. The Washington fir used in the trestles cost $16 per M delivered in the yard. The cost of framing and placing the timberwork (exclusive of the piles) was $3.25 per M.

The cost of the plant was as follows:

Machinery	$30,055.98
Piles and pile driving	13,963.00
Lumber for trestles and molds	12,094.26
Iron and castings	7,572.36
Labor on plant	15,760.40
Total	$79,446.00

The item of "labor on plant" includes all work in building trestles, laying track, building molds, mold traveler and all appurtenances for performing the work. The cost of plant per cu. yd. of concrete was estimated thus:

First cost	$79,446
20% depreciation during use on South Pier	15,889
Estimated increase in size of plant for use on North Pier	3,972
Total for both piers	$99,307
Salvage value of plant 20%	19,861
Net	$79,446

$79,446 ÷ 94,000 cu. yds. = $0.84 per cu. yd.

The proportions of the subaqueous concrete were 1:2.5:5 by volume, or 1:2.73:5.78 by weight, cement being assumed to weigh 100 lbs. per cu. ft. The proportions of the superaqueous concrete were 1:3.12:6.25 by volume, or 1:3.41:7.22 by weight. The dry sand weighed 109.2 lbs. per cu. ft., the voids being 35.1%. The pebbles weighed 115.5 lbs. per cu. ft., the voids being 31%.

As above stated, the molds were bottomless boxes built in four pieces, two sides and two ends, held together by tie-rods. The 1¼-in. turnbuckle tie-rods passed through the ends of beams that bore against the outside of the mold. These tie-rods had eyes at each end, in which rods with wedge shaped ends were inserted. The mold was erected on the trestle by the locomotive crane, and was then lifted by the mold traveler, carried and lowered to place. The largest one of these molds, with its cast-iron ballast, weighed 40 tons. When it was desired to remove a mold, after the concrete block had hardened, the nuts on the wedge-ended rods were turned, thus pulling the wedge end from the eye of the tie-rod, and releasing the sides of the mold from the ends. The locomotive crane then raised the sides and ends separately and assembled them ready to be lowered again for the next block. The time required to remove one of these 40-ton molds, reassemble and set it again rarely exceeded 60 mins., and had been accomplished in 45 mins.

As already stated, the concrete was built in alternate

blocks; then the intermediate blocks were built, the ends of the concrete blocks just built serving as end molds for the new blocks. The two sides of a mold (without the end pieces) were assembled by the aid of templates, and were bolted together by tie-rods. To hold the sides apart when the templates were removed, it was necessary to surround each of the six tie-rods with a box of 1-in. plank. These boxes measured 4 ins. square on the inside; and were left buried in the concrete. Their purpose was to act as horizontal struts to hold the sides of the mold apart, and to permit removal of the tie-rods after the concrete block had been built. The removal of these rods was accomplished by withdrawing the wedge-ended rods.

The mold traveler deserves a brief description. It was provided with a four-drum engine, and the drums were actuated by a worm gear which was positive in its movement in lowering as well as in raising. The drums act independently or together, as desired. The hoisting speed was 6 ft. per min., and the traveling speed, 100 ft. per min. The load was suspended on four hooks, depending by double blocks and ⅝-in. wire ropes from four trolleys suspended from the truss, which allowed lateral adjustment of the mold. The difficulty of using so broad a gage as 31 ft., on a curve having a radius of 563 ft., was overcome by using a defferential gear in the driving shaft of the propelling gear, thus compensating for the greater distance traveled by the wheels on the outer rail. The whole machine was carried on six trucks having two double-flanged wheels each. The four forward trucks were swiveled on steel bed plates with 3-in. king bolts. The two rear trucks were fixed to the chord and had idler wheels, which slid on their axles so as to accommodate themselves to the curve.

Cost of Concrete Base for Pavements.—In an article in Engineering News, Dec. 5, 1901, I originally gave some of the following data:

The ordinary labor cost of concrete foundations is 0.4 to 0.5 of a 10-hour day's wages per cubic yard of concrete, although occasionally it may be as low as 0.3 of a day where two mixing gangs are worked side by side under separate foremen, and under an exacting contractor. In such a case, the rivalry between the two mixing gangs where the

progress of the work can be seen at a glance, as in laying pavement foundations, will insure a saving of at least 25% in the labor item. The following, taken from my note-books and time-books, indicates the ordinary cost of concrete mixing and laying:

Case I. Laying 6-in. pavement foundation. Stone delivered and dumped upon 2-in. plank laid to receive it. If dumped directly upon the ground it costs half as much again to shovel it up. Sand and stone were dumped along the street, so that the haul in wheelbarrows to mixing board was about 40 ft. Two gangs of men worked under separate foremen, and each gang averaged 4.5 cu. yds. concrete per hour.

The labor cost was as follows for 45 cu. yds. per gang:

	Per day.	Per cu. yd.
4 men filling barrows with stone and sand ready for the mixers, wages 15 cts. per hr.	$6.00	$0.13
10 men, wheeling, mixing and shoveling to place (3 or 4 steps), wages 15 cts. per hr.	15.00	0.33
2 men ramming, wages 15 cts. per hr...	3.00	0.07
1 foreman at 30 cts. per hr. and 1 water boy, 5 cts.	3.50	0.08
Total	$27.50	$0.61

Case II. Sometimes it is desirable to know every minute detail of cost, for which purpose I give the following:

		Per cu. yd. Day's labor.	Per cu. yd. Cost.
3 men loading stones into barrows		.06	$0.09
1 man loading sand into barrows		.02	0.03
2 men ramming		.04	0.06
1 foreman and 1 water boy equivalent to		.035	0.05
9 men	wheeling sand and cement to mixing board	.02	0.03
9 men	wheeling stone to mixing board	.026	0.04
9 men	mixing mortar	.013	0.02
9 men	mixing stone and mortar	.049	0.07
9 men	placing concrete (walking 15 ft.)	.072	0.11
Total		3.35	$0.50

In one respect this is not a perfectly fair example (although it represents ordinary practice), for the mortar was only turned over once in mixing instead of three times, and the stone was turned only twice instead of three or four times. Water was used in great abundance, and by its puddling action probably secured a very fair mixture of cement and sand, and in that way secured a better mixture than would be expected from the small amount of labor expended in actual mixing. About 9 cts. more per cu. yd spent in mixing would have secured a perfect concrete without trusting to the water.

Case III. Two gangs (34 men) working under separate foremen averaged 600 sq. yds, or 100 cu. yds. of concrete per 10-hr. day for a season. This is equivalent to 3 cu. yds. per man per day. The stone and sand were wheeled to the mixing board in barrows, mixed and shoveled to place. Each gang was organized as follows:

	Per day.	Per cu.yd.
4 men loading barrows	$6.00	$0.12
9 " mixing and placing	13.50	0.27
2 " tamping	3.00	0.06
1 foreman	2.50	0.05
Total	$25.00	$0.50

These men worked with great rapidity. The above cost of 50 cts. per cu. yd. is about as low as any contractor can reasonably expect to mix and place concrete by hand in pavement work.

Case IV. Two gangs of men, 34 in all, working side by side on separate mixing boards, averaged 720 sq. yds., or 120 cu. yds., per 10-hr. day. Each gang was organized as follows:

	Per day.	Per cu.yd.
6 men loading and wheeling	$9.00	$0.15
8 " mixing and placing	12.00	0.20
2 " tamping	3.00	0.05
1 foreman	3.00	0.05
Total	$27.00	$0.45

Instead of shoveling the concrete from the mixing board into place, the mixers loaded it into barrows and wheeled it to place. The men worked with great rapidity.

Case V. Mr. Alfred F. Harley is authority for the following: In laying concrete foundations for street pavement in New Orleans, a day's work, in running three mixing boards, covering the full width of the street, averaged 900 sq. yds., 6 ins. thick, or 150 cu. yds. with a gang of 40 men. With wages assumed to be 15 cts. per hr. the labor cost was:

	Cts. per cu. yd.
6 men wheeling broken stone	6
3 " " sand	3
1 " " cement	1
2 " opening "	2
7 " dry mixing	7
8 " taking concrete off	8
3 " tamping	3
3 " grading concrete	3
1 " attending run planks	1
3 water boys	1
2 extra men and 1 foreman	4
Total labor cost	39 cts.

Case VI. The following cost of a concrete base for pavements at Toronto has been abstracted from a report (1892) of the City Engineer, Mr. Granville C. Cunningham. The concrete was 1:2½:7½ Portland; 2,430 cu. yds. were laid, the thickness being 6 ins.; at the following cost per cu. yd.:

0.77 bbl. cement, at $2.78	$2.14
0.76 cu. yd. stone, at $1.91	1.45
0.27 " " sand and gravel, at $0.80	0.22
Labor (15 cts. per hr.)	1.03
Total	$4.84

Judging by the low percentage of stone in so lean a mixture as the above, the concrete was not fully 6 ins. thick as assumed by Mr. Cunningham. Note that the labor cost was 1½ to 2 times what it would have been under a good contractor.

It is also noteworthy that Portland cement was used. Until quite recently Natural cement has been used almost exclusively in pavement foundations in America. A Natural cement concrete is usually made 1:2:5, the cement being measured loose, so that about 1.15 bbls. of cement are required per cubic yard of concrete. A sufficiently good Portland cement concrete can be made with ¾ bbl. cement per cubic yard; and I think that, if the mixing is well done in a mechanical mixer, it is safe to make concrete for pavement foundations 6 ins. thick using not more than ½ bbl. of Portland cement per cubic yard.

Case VII. Mr. Charles Apple gives the following data on the cost of a 6-in. concrete foundation for a brick pavement, at Champaign, Ill. The concrete was 1:3:3, Natural cement, mixed by hand. The material was brought to the steel mixing plate from piles 30 to 60 ft. away.

	Cost per cu. yd.
1.2 bbls. cement, at $0.50	$0.600
0.6 cu. yd. sand and gravel, at $1	0.600
0.6 " " broken stone, at $1.40	0.840
6 men turning with shovels, at $2	0.080
4 " throwing into place, at $2	0.053
2 " handling cement, at $1.75	0.023
1 " wetting with hose, at $1.75	0.012
2 " tamping, at $1.75	0.023
1 " leveling, at $1.75	0.012
6 " wheeling stone, at $1.75	0.070
4 " " gravel, at $1.75	0.047
1 foreman, at $4	0.027
Total per cu. yd.	$2.387

The cost of mixing and placing this concrete was only 35 cts. per cu. yd., a gang of 26 men and 1 foreman placing 150 cu. yds., or 900 sq. yds., per day. I do not believe these figures of Mr. Apple to be trustworthy, for reasons given on page 163.

Cost of Machine Mixing and Wagon Hauling.—Mr. D. G. Fisher, Asst. Engr., The Laclede Gas Light Co., St. Louis, has given the following data on the mixing, de-

livering and placing of Portland cement concrete for a pavement base 6 ins. thick.

The gravel was dumped from wagons into a large hopper, raised by a bucket elevator into bins, and drawn off through gates into receiving hoppers on the charging platform where the cement was added. The receiving hoppers discharged into the mixers, which discharged the mixed concrete into a loading car that dumped into wagons, which delivered it on the street where wanted. The longest haul in wagons was 30 mins., but careful tests showed that the concrete had hardened well. The wagons were patent dump wagons of the drop-bottom type.

Mr. Fisher says:

"You may consider the following figures a fair average of the plant referred to, working to its capacity. To these amounts, however, must be added the interest on the investment, the cost of wrecking the plant and the depreciation of the same, superintendence, and the pay roll that must be maintained in wet weather. I am assuming the street as already brought to grade and rolled.

"With labor at $1.75 per day of 10 hours, teams at $4, engineer and foremen at $3, and engine at $5 per day, concrete mixed and put in place by the above method costs:

	Per cu. yd.
To mix	$0.12 to $0.15
To deliver to street	0.10 to 0.14
To spread and tamp in place	0.08 to 0.11
Total	$0.30 to $0.40

"The mixers are No. 2½ Smith, sold by the Contractors' Supply and Equipment Co., Chicago, Ill., and a ½-yd. Cube, sold by Municipal Engineering & Contracting Co., Chicago.

"The Smith mixer will deliver 40 thoroughly mixed batches per hour under favorable conditions.

"The above figures are on the basis of a batch every 2 minutes, which is easily maintained by using the loading car, as by this means there will be no delay in the operation of the plant owing to the irregularity of the arrival of the teams.

"My experience leads me to believe that a better efficiency

can be obtained by using mixers of 1 cu. yd. capacity, and that the batch mixer is the only type of machine where any certainty of the proportion of the mixture is realized."

Cost of Mixing with a Gravity Mixer.—Mr. G. B. Ashcroft states that a small gravity mixer of the Peter Haines type was used in the building of a dock for The William Skinner Ship-Building & Dry Dock Co., of Baltimore, Md. It consisted of two conical hoppers, one above the other, and above these were four small pyramidal hoppers for measuring the sand and stone, and above these were small bins. On man at each conical hopper tending the gates, and two men at the pyramidal hoppers (4 men in all) constituted the gang on the mixer. A scow load of sand and another of broken stone were hauled alongside the bulkhead on which the mixer stood, and a clamshell bucket dredge was used to load the sand and stone from the scows into the bins of the mixer. Each batch was 25 cu. ft. of 1:2:5 concrete rammed into place. The record for 10 hrs. was 110 batches, making about 35 cts. per cu. yd. as the labor cost. Wages of common laborers were $1.50. The concrete was run directly into place through chutes; and the mixer was moved from place to place by means of the dredge boom.

On the Cedar Grove Reservoir, built for Newark, N. J., a large gravity mixer of the Haines type was used. A photograph of the mixing plant is given in Engineering Record, Dec. 5, 1903, and the statement is made that the best day's output of the mixer was 360 cu. yds. of 1:2:5 concrete. As a matter of fact the best day's output was 403 cu. yds.; the average output during the best month was 302 cu. yds.; and the average of the whole job was 225 cu. yds. per 10-hr. day. The stone, sand and cement were all raised by bucket elevators to the top of the high wooden tower that supported the bins and the mixer. There were 10 men operating the mixer, so that (exclusive of power, interest and depreciation) the labor cost of mixing averaged only 7 cts. per cu. yd.; and during one month it was as low as 5 cts. per cu. yd. This does not include delivering the materials to the men at the mixer, nor does it include conveying the concrete away and placing it. The work was done by contract.

Cost of Concrete Made With a Trump Mixer.—In Trans. Am. Soc. M. E., June, 1905, Mr. E. N. Trump, of Syracuse, N. Y., describes his novel device for automatically measuring the ingredients of concrete, which are delivered in a continuous stream into a paddle mixer. The stone, sand and cement are elevated into hoppers by bucket elevators, and the hoppers discharge continuously onto rotating tables, where large steel knives scrape off the proper proportions of ingredients into a chute that delivers to the mixer. The device is so simple, so effective and so remarkably cheap to operate that it is deserving of careful consideration. About 10 HP. are said to be sufficient for operating the measurer and mixer. Mr. Trump gives the following cost data:

No. 1 Concrete Experiment.—A concrete mixer was installed in a central position, where the stone, cement and sand could be elevated into hoppers by means of a system of buckets, elevated on an elevator and pushed by hand at both the bottom and the top, the labor including shoveling the sand and stone into the buckets and emptying cement from the bags. The cost of this concrete was as follows:

1 cubic yard of concrete, with a 1:3:5 mixture, weighs 3,800 lbs. and contains as follows:

4.5 cu. ft. or 1⅓ bbls. of cement, @ $1.15 per bbl...	$1.54
13.5 " " of sand	.45
22.5 " " " spalls, 1,975 lbs. @ $0.35 per net ton..	.345
For hauling sand, then elevating and placing in hopper	.021
For hauling cement, then elevating and placing in hopper	.025
Cost of mixing 50 yds. per day, labor @ $0.15 per hr.	.056
Current and motors	.01
Repairs—Average for six months	.01
Cost per cu. yd. loaded into wagons............	$2.457
Cost of making concrete exclusive of material..	0.122

The concrete machine running with the table making 5 revolutions per minute has a capacity of 50 cu. yds. per hour.

The above figures for labor are higher than they would

be if more concrete had been made, only 50 cu. yds. being the amount required.

The machine was operated by making two or three cubic yards at a time, and then stopping until more concrete was required.

No. 2 Concrete Experiment..—Foundations of a large building, the concrete being hauled in carts and dumped into trenches.

Cost of concrete loaded into wagons (as above given)	$2.45
Hauling from mixer to job	.19
Putting in place	.28
Total cost per cubic yard in place	$2.92

In the above case the concrete was made as fast as six carts could haul it 500 ft.

No. 3 Concrete Experiment.—Cost of machine shop floor, having 8-in. thickness of concrete, left with a rough surface.

Cost of concrete loaded into wagons	$2.45
Hauling from mixer to job	.175
Putting in place	.86
Total cost per cubic yard in place	$3.485

No. 4 Concrete Experiment.—Heavy foundations.

Concrete put into wheelbarrows and wheeled on plank runways about 150 ft.

Cost of concrete loaded into wheelbarrows	$2.45
Wheeling 150 feet and putting in place	.73
Total cost per cubic yard	$3.18

No. 5 Concrete Experiment.—Heavy concrete retaining walls, and concreting around a series of large pipes in a trench, hauling concrete 2,200 ft. on bad roads, and wheeling from where wagons were dumped and putting in place.

Cost of concrete loaded into wagons	$2.45
Hauling 2,200 ft. on bad roads	.26
Wheeling from wagons, dumping and putting in place	.22
Total cost per cubic yard	$2.93

Cost of Groined Arches and Forms on the Albany Filter Plant.—The following data are given by Mr. Allen Hazen and Mr. William B. Fuller, in Trans. Am. Soc. C. E. 1904. The concrete was mixed in 5-ft. cubical mixers in batches of 1.6 cu. yds. at the rate of 200 cu. yds. per mixer day. One barrel of cement, 380 lbs. net, assumed to be 3.8 cu. ft., was mixed with three volumes of sand weighing 90 lbs. per cu. ft., and five volumes of gravel weighing 100 lbs. per cu. ft. and having 40% voids. On the average 1.26 bbls. of cement were required per cu. yd. The conveying plant consisted of two trestles (each 900 ft. long) 730 ft. apart, supporting four cableways. The cables were attached to carriages, which ran on I-beams on the top of the trestles. Rope drives were used to shift the cableways along the trestle. Three-ton loads were handled in each skip. The installation of this plant was slow, and its carrying capacity was less than expected. It was found best to deliver the skips of concrete to the cableway on small railway track, although the original plan had been to move the cableways horizontally along the trestle at the same time that the skip was traveling.

The cost of mixing and placing the concrete was as follows:

	Per cu. yd.
Measuring, mixing and loading	$0.20
Transporting by rail and cables	0.12
Laying and tamping floors and walls including setting forms	0.22
Total	$0.54

The cost of laying and tamping the concrete on the vaulting was 14 cts. per cu. yd. The vaulting is a groined arch 6 ins. thick at the crown and 2½ ft. thick at the piers.

The lumber of the centering for the vaulting was spruce for the ribs and posts, and 1-in. hemlock for the lagging. The centering was all cut by machinery, the ribs put together to a template, and the lagging sawed to proper bevels and lengths. The centers were made so that they could be taken down in sections and used again. The cost of centering was as follows:

Labor on centers covering 62,560 sq. ft.

Foreman, 435 hrs. at 35 cts.	$152.25
Carpenters, 4,873 hrs. at 22½ cts.	1,096.42
Laborers, 3.447 hrs. at 15 cts.	517.05
Painters, 577 hrs. at 15 cts.	86.55
Teaming, 324 hrs. at 40 cts.	121.60
Total labor building centers 313 M at $6.37	$1,973.87

Materials for centers covering 62,560 sq. ft.

313,000 ft. B. M. lumber, at $18.20	$5,700.00
3,700 lbs. nails, at 3 cts.	111.00
8 bbls. tar, at $3	24.00
Total	$5,835.00

These centers covered two filters, each having an area of 121⅓ × 258 ft. There were six more filters of the same size, for which the same centers were used. The cost of taking down, moving and putting up these centers (313 M) three times was as follows:

Foreman, 2,359 hrs. at 35 cts.	$825.65
Carpenters, 12,766 hrs. at 22½ cts.	2,872.35
Laborers, 24,062 hrs. at 15 cts.	3,609.30
Team, 430 hrs. at 40 cts.	172.00
3,000 ft. B. M. lumber, at $20	60.00
3,000 lbs. nails, at 3 cts.	90.00
Total cost moving centers to cover 196,660 sq. ft.	$7,629.30

The cost of moving the centers each time was $8.10 per M, showing that they were practically rebuilt; for the first building of the centers, as above shown, cost only $6.37 per M. In other words, the centers were not designed so as to be moved in sections as they should have been. Although the centers were used four times in all, the lumber was in fit condition for further use. The cost of the labor and lumber for the building and moving of these centers for the 8 filter beds, having a total area of 259,220 sq. ft., was $15,438, or 6 cts. per sq. ft.

Cost of Lining a Water-Works Tunnel.—In Trans. Am. Soc. C. E., Vol. 31, p. 294, Mr. Desmond Fitz Gerald describes the lining of a water-works tunnel with concrete. The tunnel passes through Beech Street, Boston, and is in a conglomerate rock. It was built in 1875 and was lined with concrete, 12 ins. thick, in 1889-1892, the tunnel inside the lining having a horse-shoe shape, 9 ft. in diameter. The water was shut off four days out of every week while work was in progress. All work was done by day labor and was very expensive, the cost being $16.15 per cu. yd. of concrete for lining 1,182 ft. of tunnel, or at a cost of nearly $50 per lin. ft.! The progress was 6.36 ft. of tunnel lined per day for 186 days worked. I have abstracted the following data to illustrate how very expensive day labor work often is compared with work done by contract.

A track having a 2-ft. gage, and a length of 4,000 ft., was laid in the bottom of the aqueduct and the tunnel, the track being supported on a small trestle, which is illustrated and described in detail. There were 75 centers spaced 4 ft. apart and lagged with 2 × 4-in., containing in all 14 M ft. of spruce, which cost $100 per M in place! The gang of men was as follows:

2 men screening sand.
1 " shoveling sand.
2 " shoveling stone.
1 " opening cement.
7 " transporting materials on cars.
5 " mixing concrete.
2 " conveying concrete on cars.
2 " unloading concrete.
4 " spreading and ramming.
4 " digging foundation piers, pumping water and preparing centers.
3 " taking down and helping set up centers.
3 " taking nails out of lagging, scraping and washing lagging.
3 carpenters setting centers and building drains.
1 foreman.
1 superintendent.
—
41 total gang.

This gang worked in the tunnel four days weekly, and worked the other two days elsewhere. The number of cubic yards of concrete placed daily by this large gang of men was only 18 cu. yds., or less than ½ cu. yd. per man per day! The average distance that the material was transported in cars was 2,700 ft., and 192 bbls. of cement, sand and stone were rammed by 7 men daily. Three of these men pushed a car holding 11 bbls. of material, making 8 trips a day. The distance traveled per man per day was only 7.66 miles. These men also unloaded their cars, thus shoveling 27.4 bbls. (or 3.4 cu. yds.) besides. Loaded cars had right of way, and returning empty cars had to make quick trips from switch to switch. It is apparent from the cost data given that the men were a lazy lot.

Some interesting measurements were made showing the shrinkage of sand and stone. It was found that a barrel of sand shoveled into a measuring box measured 3.42 cu. ft., but this sand when allowed to drop 12 ft. through a chute into the cars measured 7% less. A barrel of stone averaged 3.37 cu. ft., but upon falling 12 ft. the stone was compacted 9%. As the materials were measured compacted in the cars, the 1:2:5 concrete contained 1 bbl. of cement, 2 1-6 bbls. of loose sand, and 5½ bbls. of loose stone. By actual measure this was found to make 20 cu. ft. of thoroughly rammed concrete. The concrete in the tunnel was not so compact, however, as it measured 21 cu. ft. per batch, 1.3 bbls. of Portland cement being used per cubic yard of concrete, so that it required 38 cu. ft. of cement, sand and stone to make 1 cu. yd. of concrete. The stone was the "run of the crusher." A cement barrel was put into a box, surrounded with concrete, and filled with water. It took 3.425 cu. ft. of water to fill the barrel between the heads. The sand and stone were measured in barrels with one head out and therefore measured more. Two barrels of sand and one of cement mixed 5 times dry still fill three barrels, but the moment water is added shrinkage occurs.

Cost of Making Blocks for a Concrete Sewer.—At Coldwater, Mich., in 1901, there was built a concrete sewer with a monolithic invert and an arch of concrete blocks. Riggs & Sherman, of Toledo, O., designed the sewer, and H. V. Gifford, of Bradner, O., was in charge of construction.

The sewer was circular, having an inner diameter of 42 ins., the thickness of the invert and the arch alike was 8 ins. The concrete was 1 of Portland cement to 6 of gravel. There were 11 concrete blocks in the ring of the arch, each block being 24 ins. long, 8 ins. thick, 8 ins. wide on the outside of the arch and 5¾ ins. wide on the inside of the arch. A block weighed 90 lbs. which was too heavy for rapid laying; blocks 18 ins. long would have been better. Some 8,500 blocks were made. Molds were of 2-in. lumber, lined with tin, for after a little use it was found the concrete would stick to the wood when the mold was removed. The four sides of the mold formed the extrados, the intrados, and the two ends of the block; the other two sides being left open. When put together the mold was laid upon a 1-in. board, 12 × 30 ins., reinforced by cleats across the bottom. The sides of the molds were held together with screws or wedge clamps. When the blocks had set, the sides of the molds were removed, and the blocks were left on the 12 × 30-in. boards for 3 days, then piled up, being watered several times each day for a week.

A gang of 14 men made the blocks; 2 screening gravel through 1-in. mesh screen; 4 mixing concrete; 4 molders; 3 shifting and watering blocks; and 1 foreman. With a little practice each molder could turn out 175 blocks a day; and since each block measured ¾ cu. ft., the output of the 14 men was 19½ cu. yds. a day. Mr. Gifford informs me that the wages were $1.50 a day for all the men, except the foreman. The daily wages of the 14 men were $22, so that the labor of making the blocks was $1.10 per cu. yd.

Each batch of concrete, containing ½ bbl. of Portland cement costing $1.35 per bbl., made 18 blocks. (1 bbl. per cu. yd.) Since the gravel cost nothing, except the labor of screening it, the total cost of each block was 11 to 12 cts., which includes 0.85 cent for use of molds and mold boards, which were an entire loss. At 12 cts. per block the cost was $4.32 per cu. yd.

The contract price was $3 per lin. ft. of this sewer, as against a bid of $3.40 per ft. for a brick sewer.

When the trenching had reached to the level of the top of the invert, two rows of stakes were driven in the bottom, stakes being 6 ft. apart in each row, and rows being a distance apart ¼-in. greater than the outer diameter

of the sewer. These stakes were driven to such a grade that the top of a 2 × 4-in. cap or "runner" set edgewise on top of them was at the proper grade of the top of the invert. The excavation for the invert was then begun, and finished to the proper curve by the aid of a templet drawn along the 2 × 4-in. runners. In gravel it was impossible to hold the true curve of the invert bottom. Concrete was then placed for the invert. To hold up the sides of the invert concrete, a board served as a support for the insides, but regular forms were more satisfactory in every respect except that they were in the way of the workmen. A form was tried, its length being 6 ft. It was built like the center for an arch, except that the sheeting was omitted on the lower part of the invert. It was suspended from cross-pieces resting on the "runners." After the concrete had been rounded in place, the form was removed and the invert trued up. This form worked well in soil that could be excavated a number of feet ahead, so that the forms could be drawn ahead instead of having to be lifted out; but in soil, where the concreting must immediately follow the excavation for the invert, the form is in the way. The invert was trued up by drawing along the runners a semicircular templet having a radius of 21½ ins. Then a ½-in. coat of 1:2 mortar was roughly troweled on the green concrete. Another templet having a 21-in. radius was then drawn along the runners to finish the invert.

When the plaster had hardened, two courses of concrete blocks were laid on each shoulder of the invert, using a 1:2:¼ mortar, the ¼ part being lime paste. The lime made the mortar more plastic and easier to trowel. Then the form for the arch was placed, and as each 8-ft. section of the arch was built, a grout of 1:1 mortar was poured over the top to fill the joints. Earth was thrown on each shoulder and tamped, and the center moved ahead.

Common laborers were used for all the invert work, except the plastering which was done by masons who were paid 30 cts. per hr. Masons were also used to lay the concrete blocks in the arch. Mr. Gifford states that two masons would lay at the rate of 100 lin. ft. of arch per day, if enough invert were prepared in advance. As there were 11 blocks in the ring of the arch, this rate would be equivalent to 7½ cu. yds. of arch laid per mason per day.

Cost of Concrete Block Manholes.—Mr. Hugh C. Baker, Jr., gives the following:

The cost of making concrete block manholes at Rye, N. Y., was as follows per manhole:

30 blocks for walls, 2.5 cu. yds. of 1:2:5 concrete..	$21.00
6 blocks for cover, ½ cu. yd. reinforced concrete....	4.27
I-beams for cover, in place	5.40
Supervision, freight and hauling, 5.6 tons concrete..	9.38
3 hrs. labor placing cover at 15 cts.................	0.45
20 hrs. labor placing walls at 15 cts...............	3.00
Total per manhole, exclusive of iron cover..	$43.50

Each manhole was 5 ft. deep inside, 8-in. walls, 5 ft. in diameter. All concrete was handmixed, very wet, ¾-in. stone being used. A set of 30 wooden molds for the wall blocks was made. These molds cost from $3.50 to $12 each; some being made of hard wood lined with zinc. In making the blocks 4 men averaged 15 wall blocks a day of about 2½ cu. ft. each, which is equivalent to 0.84 cu. yd. per man per day. The concrete was allowed to set 3 to 12 hrs. before removing the molds; 24 to 36 hrs. before taking the blocks outside to dry; and 7 days before shipping the blocks. About 1,000 blocks were made and only 9 lost by breaking.

For comparison it is well to give the cost of brick manholes, as follows:

1,450 brick at $8.25 per M.	$11.96
Mason	6.00
46 hrs. labor at 15 cts.............................	6.90
4 bbls. cement at $1.25	5.00
Sand	.75
Supervision, etc.	2.50
Concrete top blocks (½ cu. yd.) and I-beams	11.40
Total	$44.51

This brick manhole had a flat concrete top.

Cost of Conduit Foundation and Invert.—Mr. Henry H. Carter gives the following data on the building of 2,500 cu. yds. of concrete for a foundation and invert of the

Farm Pond conduit. The work was done in about 100 days in 1885 for the city of Boston by day labor (not by contract), at a cost of $4.21 per cu. yd., distributed thus:

	Per cu. yd.
Foreman, at $2.75	$0.16
Laborers, 20 at $1.65	1.22
Carpenters, 2 at $2.25	0.15
Horse and car, at $3.15	0.15
Miscellaneous labor	0.01
Total labor	$1.69
1.32 bbls. natural cement	$1.66
0.38 cu. yd. sand at $1.20	0.45
1 cu. yd. gravel at $1.20	1.20
Wasted cement, etc.	0.03
Total materials in concrete	$3.34
Lumber for forms, $125	$0.05
Cement shed, $100	0.04
Cars, $66	0.03
Tools, loss and depreciation, $25	0.01
Boiler (20 days), $20	0.01
Pumps (100 days), $25	0.01
Coal for pumps, 12 tons, $72	0.03
Total plant	$0.18

Cost of Concrete-Steel Building Columns.—Mr. Keith O. Guthrie gives the following data: Brick columns of the station of the Louisville Lighting Co. laid in lime mortar, in 10 years became so lacking in strength that they were cut out, and concrete-steel columns substituted. The design and dimensions of these columns are shown in Fig. 17. The building was shored, and a light movable scaffolding (4 × 6 ft. × 50 ft. high) was built from which to cut away the old brick and build the concrete. There were 12 columns, and the scaffolding was taken down and moved from column to column at a cost of $2.94 each move. The 12 cu. yds. of brick masonry in each column were cut out by two men with a drill and sledge in about

15 hrs., at a cost of 70 cts. per cu. yd., including removal to the street. Then the eight reinforcing bars were set up; 15-ft. lengths of iron were used, spliced with 2¾-in. bolts, and distanced by side bars and cross bolts at the splices. This formed a cage easily held in place. Concrete was mixed in 6 cu. ft. batches at the foot of the column by three men, with a fourth turning over and filling buckets. A fifth man received the buckets on the scaffold, as fast as they were hoisted, and dumped them into the form, where a sixth man tamped with a short iron bar and with his feet. The buckets were of galvanized iron, 12 ins. in diam. and 16 ins. high—just about all a man can handle full of concrete.

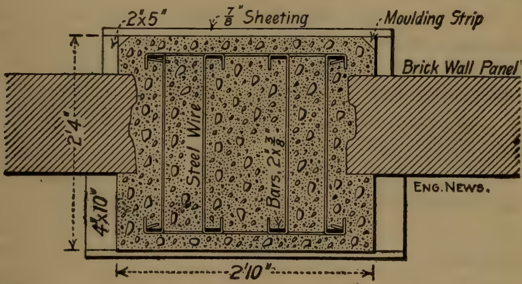


FIG. 17.

After tamping each batch, which raised the level of the concrete 15 ins., the man inside the form hooked six cross ties of No. 6 steel wire on the reinforcing bars, as shown. The ties were bent by hand in a vise at a cost of less than 1 ct. each for labor. A mule driven by a man hoisted the buckets, wages being $1 a day for the mule and $1.50 for the driver; the cost of hoisting being 25 to 40 cts. per cu. yd. depending upon the rapidity of the man inside the column. It took from 1½ to 2 days to concrete a column of 12 cu. yds. "The work could have been done in half the time had the man inside been able to handle the material." The concrete was 1:3.8:5.7; the stone being limestone "screenings." It was deposited wet enough to be easily pushed into corners. A good surface was secured except where leaks in the forms drained off the mortar.

This fault was overcome by the use of triangular molding strips (1½ ins. on a side) of poplar tacked in the corners of the forms, making them water tight. Two faces of the columns were painted with grout. The building vibrated excessively during the concreting, due to a high speed engine that was running; but this vibration disappeared as the cement hardened, until only a tremor remained.

Mr. Guthrie informs me that the heavy lumber for shoring cost $23 per M and was used 4 times. The light lumber for forms cost $18 per M. All lumber was yellow pine. The forms for one column required 650 ft. B. M.; and on an average the forms were used twice. As a matter of fact the side strips and outside braces were used 3 times, while much of the ⅞-in. sheeting was destroyed after one usage, although heavy oil was used to save it from the killing effect of wet concrete. Tongue and groove boards can not be shifted to advantage, regardless of their thickness. For light work 1¼ × 9 in. square dressed stuff is the handiest and most lasting.

All labor (negroes), 15 cts. per hr.; foreman (who worked), 22½ cts. per hr.

Concrete.	Cost per column.	Cost per cu. yd.
Lumber for forms	$4.81	$0.40
Setting up and removing forms	11.32	0.95
Cement, 10.17 bbls. at $2.40	24.40	2.03
Sand, 5.87 yds. at $0.90	5.28	0.44
Stone, 8.75 yds. at $1.35	10.94	0.91
Mixing and wheeling	15.73	1.31
Hoisting by mule with driver	4.80	0.40
Handling bucket on scaffold	2.93	0.25
Tamping inside column	2.93	0.25
Painting with grout	3.89	0.32
Clearing away rubbish	1.97	0.16
Rigging, etc.	2.64	0.21
Tools	0.59	0.05
Moving scaffold	2.94	0.25
Moving mix board and rigging hoist	1.62	0.14
Total cost of concrete	$96.79	$8.07

	Cost per column.	Cost cts. per lb. of bars.
Iron bars, 1,034 lbs.	$20.68	2.00
Drilling iron bars	1.44	0.14
Setting iron bars in place	1.23	0.12
Bolts for splicing and spacing	3.98	0.40
Wire cross ties at 2½ cts. lb.	1.39	0.14
Labor forming 130 cross ties	1.13	0.11
Total cost of iron and steel	$29.85	2.91

Summary of Cost.

	Per column.	Per cu. yd.
Concrete in place	$96.79	$8.07
Steel in place	29.85	2.49
Cutting out and removing brick	8.36	0.70
Shoring floors and roof, labor	5.87	0.49
Ditto for lumber used 3 times	3.44	0.29
Total	$144.31	$12.04

Cost of Mixing and Placing Concrete for a Building.—The following relates to the placing of concrete in the walls, floors and columns of a concrete-steel building. The concrete was mixed in a Smith mixer driven by a gasoline engine. It was dumped from the mixer through a pivoted chute into two 10-cu. ft. buckets on a flat car, and hauled by a horse to one of the two cableways which raised and delivered the buckets to the platforms where the buckets were dumped. Men then shoveled the concrete into wheelbarrows and delivered it where wanted. The crew at the concrete mixer was organized as follows: 14 men loaded wooden skips with the required proportion of sand for a batch, the sand being shoveled into a bottomless measuring box laid on the bottom of the skip. After loading the sand, the broken stone was wheeled in barrows and dumped into the skip. A derrick then hoisted the skip which was dumped by two men into a chute leading to the mixer. These same two men fed in the necessary number of bags of cement, and the water. Each batch of concrete was ¾ cu. yd., and the

mixer averaged 200 batches, or 150 cu. yds. a day. The best day's run was 246 batches. The cost of mixing and placing the concrete was as follows:

	Per day.
14 men loading skips with sand and stone	$21.00
1 tag-rope man swinging derrick boom	1.75
1 derrick engineman	2.50
2 men feeding mixer	3.00
1 man (foreman) dumping mixer	2.50
10 gals. gasoline for mixer engine	1.25
⅓ ton coal for derrick engine	1.50
6 horses on 6 cars	9.00
6 drivers for same	9.00
2 men receiving cars, left side of building	3.00
2 men receiving cars, right side of building	3.00
2 cableway enginemen	6.00
1 ton coal for cableways	4.50
2 signal men	3.00
2 men dumping buckets	3.00
10 men loading and wheeling	15.00
4 men placing concrete	6.00
1 superintendent	6.00
Total, 150 cu. yds., at 67 cts	$101.00

The concrete was mixed "sloppy," so that it required only a small amount of spading. The cost of forms and of placing the steel before concreting is not available.

Cost of Concrete Building Blocks.—In Engineering News, April 6, 1905, Mr. L. L. Bingham gives the following data. Letters were sent to more than a hundred makers of concrete blocks in Iowa. Most of the replies gave data relating to blocks for walls 10 ins. thick. The average cost per square foot of blocks for a 10-in. wall was:

Sand	2.0 cts.
Cement, at $1.60 per bbl	4.5 cts.
Labor, at $1.83 per day	3.8 cts.
Total, per sq. ft.	10.3 cts.

The labor of making the blocks includes mixing, molding, sprinkling, piling and re-piling during or after curing. The average output per man was 48½ sq. ft. (1⅔ cu. yds.) per day.

The 10½ cts., however, does not include all costs of manufacture, for it does not include interest, depreciation and repairs, purchase of improved machinery, superin-

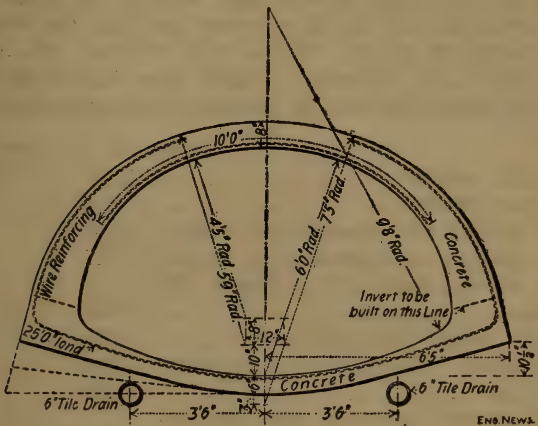


FIG. 18.

tendence and office expense. One maker who turned out 20,000 blocks (40 car loads) had a general expense of nearly 5 cts. per sq. ft., besides the above given 10½ cts. The selling price of 10-in. blocks averaged 21 cts. per sq. ft. of wall.

Cost of a Concrete-Steel Sewer.—Mr. Geo. S. Pierson gives the following data:

A concrete-steel sewer 1,080 ft. long at Kalamazoo, Mich., was begun Nov. 3, 1902, and finished Jan. 10, 1903. The work was done by day labor for the city. Much of the work was done at a temperature of 12° to 25°. The sewer arch has a span of 9 ft. 10 ins., and the sewer is 6 ft. high from invert to crown. The arch is 8 ins. thick at the crown, and the invert is 6 ins thick, Fig. 18. The concrete was reinforced with woven wire fabric of No. 11 steel wires.

The concrete was 1 cement to 6 gravel and sand, but this proportion was not strictly adhered to. The centers were built in sections 12½ ft. long, and there were 6 arch sections and 12 invert sections. The ribs for the arch centers were of 2-in. pine, and were 2 ft. apart. The sheeting was 1-in. dressed white pine. The average gang was 10 men mixing and wheeling concrete, 5 men placing and ramming, and 4½ men moving and setting up forms. This gang averaged 18.6 lin. ft. of sewer per day, the best day's work being 28 lin. ft. There were 0.95 cu. yds. of concrete per lin. ft. of sewer. Wages were $1.75 a day. The cost per lineal foot was as follows, including superintendence:

	Per lin. ft.	Per cu. yd.
1.18 bbls. cement	$2.44	$2.56
Sand and gravel	0.42	0.44
Labor mixing and wheeling (10 men)	0.98	1.03
Labor placing and ramming (5 men)	0.47	0.50
Labor moving and setting forms (4½ men)	0.43	0.45
Cost of forms and templates	0.30	0.32
Metal fabric (175 lin. ft. No. 11 wire)	0.39	0.41
Finishing	0.09	0.10
Tools, general expenses and superintendence	0.43	0.45
Total	$5.95	$6.26

The cost of excavation and backfilling is not included.

It will be noted that the cost of moving and setting the forms was unnecessarily high. Compare this cost of 45 cts. per cu. yd. with the 5 cts. per cu. yd., at Wilmington, Del., in the next case cited.

Cost of Concrete-Steel Sewer, Wilmington, Del.—Mr. T. Chalkley Hatton, M. Am. Soc. C. E., gives the following data: Fig. 19 shows a profile of Price's Run Sewer, Wilmington, Del., built in 1903, by day labor for the city, the working day being 8 hrs. long. Fig. 20 shows cross-sections at different points. The notable feature is the boldness in the design of such thin concrete shells for sewers of such large diameters. The cross-sections of

sewers in trenches deep enough to cover the arch are marked "deep cutting"; the sections where the arch projects above the ground surface are marked "light cutting." The section through the marsh was 700 ft. long, the cutting being 8 ft. deep, and at high tide the marsh was flooded 1 to 4 ft. The material was a soft mud that would pull a tight rubber boot from a workman's foot. The cost of this marsh excavation including cofferdams, underdraining, pumping, etc., was $4.60 per cu. yd. For 1,100 ft. the 9¼ ft. sewer was through a cut 22 to 34 ft. deep, the material being clay underlaid by granite. A Carson-Lidger-

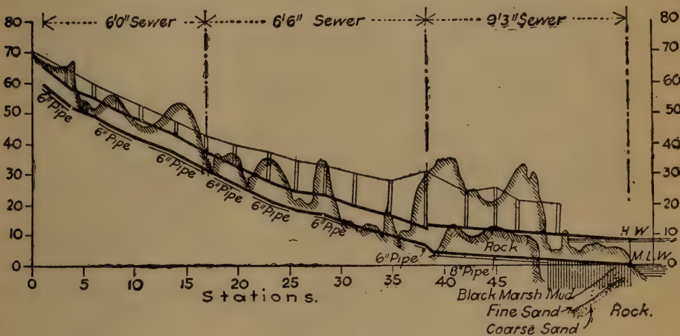


FIG. 19.

wood cableway was used. Although the crown of the arch was but 8 ins. thick, it withstood the shock of dumping 1 cu. yd. buckets of earth and rock from heights of 3 to 10 ft.; and the weight of 25 ft. of loose filling caused no cracks in the concrete.

Concrete was placed in 4-in. layers (the depth of the lagging) and well rammed, since it was found that "wet" concrete left small honeycombed spaces on the inner surface. Concrete for the invert was 1:2:6, the stone being 1½-in. and smaller, and the sand being crusher dust. The arch was 1:2:5.

The reinforcing metal used in the 9½-ft. sewer was No. 6 expanded metal, 6-in. mesh, in sheets 8 × 5½ ft., supplied by Merritt & Co., of Philadelphia. A single layer was placed around the sewer, 2 ins. from the inner surface, its position being carefully maintained by the men ramming,

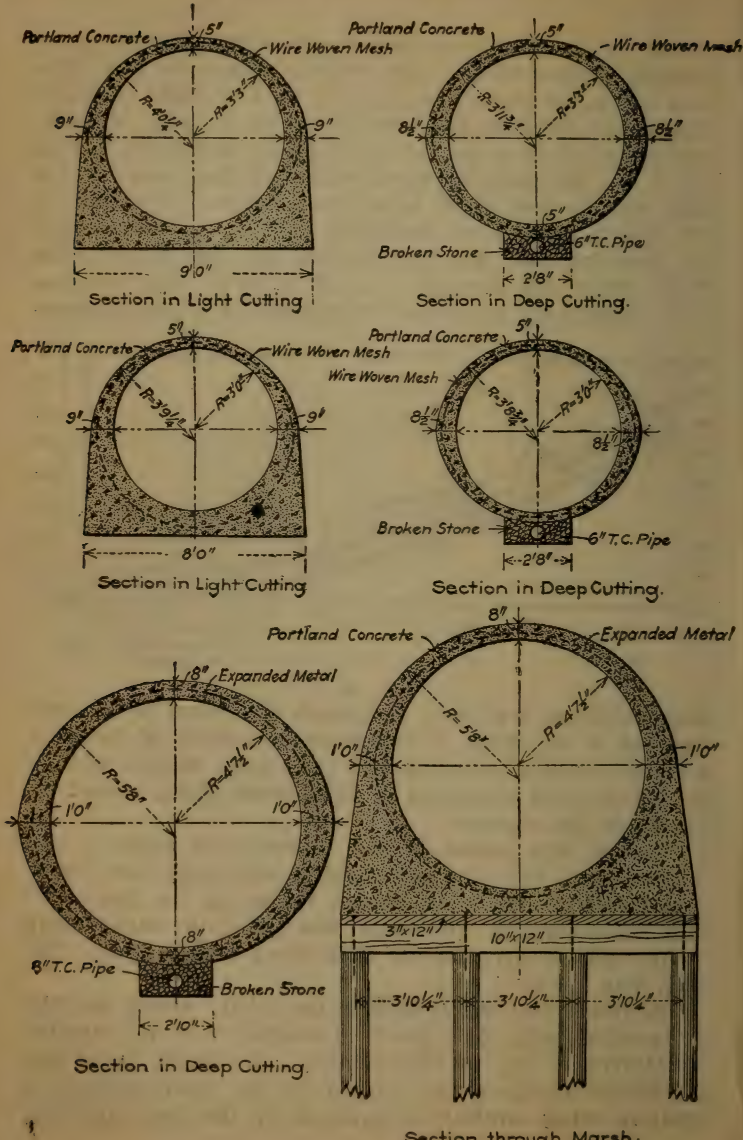

Portland Concrete
5"
Wire Woven Mesh
9"
9"
9'0"
Section in Light Cutting
Portland Concrete
5"
Wire Woven Mesh
$8\frac{1}{2}$"
$8\frac{1}{2}$"
5"
Broken Stone
6" T.C. Pipe
2'8"
Section in Deep Cutting.
Portland Concrete
5"
Wire Woven Mesh
9"
9"
8'0"
Section in Light Cutting
Portland Concrete
5"
Wire Woven Mesh
$8\frac{1}{2}$"
$8\frac{1}{2}$"
Broken Stone
6" T.C. Pipe
2'8"
Section in Deep Cutting.
8"
Expanded Metal
R=5'8"
$R=4'7\frac{1}{2}$"
1'0"
1'0"
8"
8" T.C. Pipe
Broken Stone
2'10"
Section in Deep Cutting.
Portland Concrete
8"
Expanded Metal
R=5'8"
$R=4'7\frac{1}{2}$"
1'0"
1'0"
3"x12"
10"x12"
$3'10\frac{1}{4}$"
$3'10\frac{1}{4}$"
$3'10\frac{1}{4}$"
Section through Marsh.

FIG. 20.

and with but little difficulty as the sheets were first bent to the radius of the circle. Each sheet was lapped one mesh (6 ins.) over its neighbor at both ends and sides, and no sheets were wired except the top ones, which were liable to displacement by men walking over them.

The metal used on the rest of the work was a wire-woven fabric furnished by the Wight-Easton-Townsend Co., of New York. This fabric comes in rolls 5½ ft. wide and 100 ft. to the roll. The wire is No. 8, with a 6 × 4-in. mesh. This fabric was placed by first cutting the sheets to the required length to surround the sewer entirely, embedding it in the concrete as fast as concrete was placed, in the same manner as was done with the expanded metal, except over the center where, on account of its pliability, the fabric was held the proper distance from the lagging by a number of 2-in. blocks which were removed as the concrete was placed. The wire cloth, being all in one sheet, can be placed a little more expeditiously than expanded metal, but, on the other hand, the expanded metal holds its position better in the concrete, since it is more rigid.

I quote now from Mr. Hatton's letter to me: "The major portion of concrete was mixed by machine at a cost of 66 cents per yard, including wheeling to place, coal and running of mixing machine, wages being $1.50 per day of 8 hrs. Stone was delivered alongside of machine and all material had to be wheeled in barrows upon the platform, and after mixing to the sewer. Placing and ramming concrete around the forms cost 39 cts. per cu. yd., additional. Setting forms in invert cost 2 cts. per cu. yd., setting centers 7 cts. per cu. yd. Cost of setting forms and centers includes placing steel metal. Each lineal foot of 9¼-ft. sewer contained 1 cu. yd. of concrete, although the section only calls for 0.94 cu. yd. The excess was usually wasted by falling over sides of forms or being made too thick at crown.

"This yard of 1:2:5 concrete cost in place as follows (record taken as an average of several days' run):

Cement, 1.31 bbls. at $1.30	$1.703
Stone, 0.84 cu. yds. at $1.21	1.016
Stone dust, 0.42 cu. yd. at $1.21	0.508

Labor at 18¾ cts. per hour	0.987
Labor setting forms and setting metal	0.045
Cost of forms (distributed over 1,800 ft. of sewer)	0.082
40 sq. ft. expanded metal at 4¼ cts	1.700
Labor plastering invert	0.070
Cost per ft., or per cu. yd	$6.111

"The forms for the invert were made of 2-in. rough hemlock boards cut out 4 ins. less diameter than the diameter of the sewer, except for 18 ins. at the bottom of the form which coincided with the inside form of sewer. The bottom of the sewers was laid to the bottom of this form before it was set. Then the lagging, consisting of 2 × 6-in. × 16-ft. hemlock planed, was placed against each side of the form, one at a time, and the concrete brought to the line of this top in 6-in. layers until the whole invert was finished. These forms were set in 16 ft. sections, five to each section.

"The centers consisted of seven ribs of 2-in. hemlock upon which was nailed 1½-in. lagging, 2 ins. wide, tongued and grooved, and were 16 ft. long, non-collapsable, but had one wing on each side, 9 ins. wide, which could be wedged out to fit any inaccuracies in the invert. We used four of these centers setting two at each operation and worked from two ends. We left the centers in for 18 hours before drawing.

"The cost of the concrete on the smaller sewers was the same as are the larger sewers, but the steel metal cost less, as it was wire woven metal that cost 2½ cts. per sq. ft. It was much easier handled and cut to no waste as it came in long rolls and was very pliable.

"After training our men, which occupied about one week or 10 days, we had no difficulty in getting the concrete well placed around the metal, preserving the proper location of the latter, which, however, bore constant watching, as a careless workman would often take the temporary supporting blocks and allow the metal to rest against the wooden center, in which case the metal would show through the surface inside of the sewer. The metal was kept 2 ins. away from the inside forms and the arch. To keep it at this location we had several 2-in. wooden blocks cut which were

slipped under the wire or expanded metal and as soon as some concrete was pushed under the wire at this point the block was removed.

"After the forms were removed the invert needed plastering, but the arch was practically like a smoothly plastered wall except where it joined the invert, where it frequently showed the result of too much hurry in depositing the first loads of concrete on the arch. We remedied this by requiring less concrete to be deposited at the start, thus giving the rammers time to place the material properly.

"An interesting result was obtained in the smoothness of the inside surface by using a mixture of different sized stones. When ¾-in. stones or smaller were used in the arch, the inside was honeycombed; but, where 1 to 1½-in. stones (nothing smaller) were used, the inside was perfectly smooth, and the same was true of the invert, showing that the use of larger stones is an advantage and secures more monolithic work. When the run of the crusher from 1½ to ¾-in. stones was used the work was not at all satisfactory.

"The difference in cost of mixing by hand and machine is practically nothing on this kind of work. As the moving of the machine to keep pace with the progress of the work equals the extra cost of mixing by hand when the mixing can be done close to the point where the cement is being placed."

The total cost of the sewers, including excavation, etc., was:

	Cost per lin. ft.
9¼-ft. sewer through marsh	$32.00
9¼-ft. sewer in cut averaging 24½ ft.	24.00
6½-ft. sewer in cut averaging 12 ft.	10.00
5-ft. sewer in cut averaging 11½ ft.	6.70

Cost of Concrete-Steel Sewer at Cleveland, O.—Mr. Walter C. Parmley, M. Am. Soc C. E., gives the following data: There were 3½ miles of concrete-steel sewer, 13½ ft. diameter, of section shown in Fig. 21 (taken from a cut in Engineering Record, Aug. 29, 1903). The contract price was $62 per lin. ft., including excavation, and the excavation averaged 20 cu. yds. per lin. ft. The bid for a brick sewer was $75 per lin. ft.

It will be noted that there are two rows of "anchor bars" buried in the side walls. The invert and side walls were first built up as high as the top of the brick lining, then the arch centers were placed, and the steel skeleton was bolted to the anchor bars. The ribs of this steel skeleton were spaced 15 ins. centers, and there were 8 rows of horizontal or longitudinal bars of $1\frac{1}{2} \times \frac{1}{4}$-in. steel bolted to the ribs. The metal was all bent to shape in the shop, so that there was no field work except to place and bolt the metal

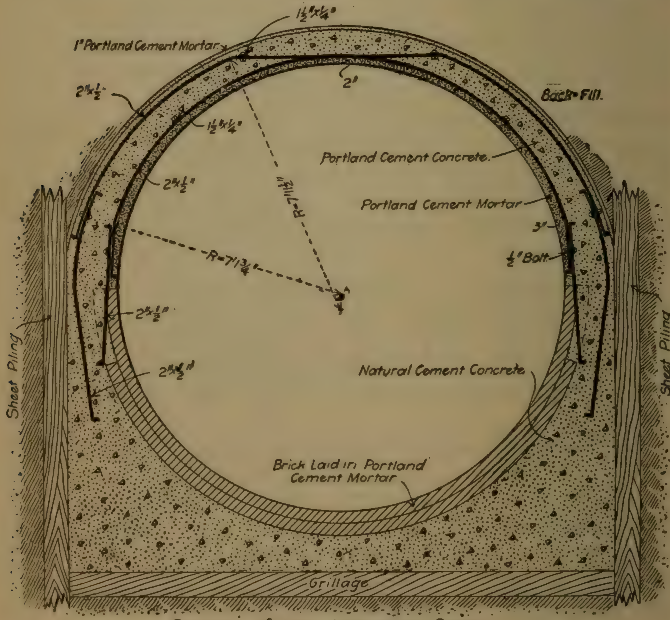


FIG. 21.

together. There were 93 lbs. of steel per lin. ft. of sewer. This design of steel skeleton was patented by Mr. Parmley.

The lagging of the arch centers was covered with building paper water-proofed with parafine. Then Portland cement mortar 2 to 3 ins. thick was plastered on the paper, so as to form the interior finish of the arch. Then the con-

crete for the arch was placed and rammed, being 12 ins. thick at the crown and 15 ins. thick at the spring line. No outside forms were used on the arch. The arch concrete was 1:3:7½. When the paper lining was pulled off a smooth surface was left. The invert concrete was made with natural cement.

Mr. Parmley had an inspector keep a record of progress for several days on the work, when the men did not know they were being timed. He informs me that an 8-hour shift was worked. The labor cost of building 40 lin. ft. of 13½-ft. concrete-steel sewer was as follows:

Cost of Labor on 40 lin. ft. of Sewer.

Labor placing anchor bars (1,500 lbs):	
1 man 1 day, at $3.50	$3.50
1 man 1 day, at $1.75	1.75
1 man ½ day, at $1.60	0.80
Placing 1,500 lbs. steel, at 0.4 cts	$6.05
Labor on concrete invert and side walls:	
5 men mixing and wheeling, at $1.75	$8.75
1 man tamping	1.75
1 man carrying concrete	1.75
⅔ man lowering concrete, at $2.25	1.50
Labor, 13 cu. yds. concrete, at $1.06	$13.75
Labor on shale brick lining (2 rings):	
2 masons, at $5.60	$11.20
1 man mixing mortar	2.25
3 men wheeling sand, filling buckets and dumping, at $1.75	5.25
⅓ man lowering materials, at $2.25	0.75
Labor, 6.38 cu. yds. brick work, at $3.05	$19.45
Labor on concrete arch:	
1 man putting mortar lining on centers, 3 days, at $1.75	$ 5.25
2 men mixing mortar, screening and wheeling sand, 3 days, at $1.75	10.50

8 men on mixing board, 3 days, at $1.75	$42.00
1 man tamping, 3 days, at $1.75	5.25
Labor, 72 cu. yds., at $0.87	$63.00

Labor placing centers and steel skeleton:

1 man, 3 days, at $3.50	$10.50
2 men, 3 days, at $1.75	10.50
Labor, 40 lin. ft., at 52½ cts. per ft.	$21.00

There were 56 lbs. of steel skeleton per lin. ft., and about ⅓ the time of this last gang of 3 men was spent in placing the metal, ⅔ being spent in moving and placing the centers; so the labor cost 0.3 cts. per lb. of steel, and the labor moving centers cost 35 cts. per lin. ft. of sewer. The back filling was begun 6 to 12 hrs. after the arch was built, but the centers were left in place 14 days.

On another section of this sewer a six-day observation showed the labor cost (hand work, no machine mixers) was 81 cts. per cu. yd. of concrete in the invert and side walls, and 70 cts. per cu. yd. on the concrete in the arch; 36 cts. per lin. ft. for placing centers, and 18 cts. per lin. ft. for placing the steel skeleton; 0.32 cts. per lb. for placing the anchor rods. A gang of 2 brick masons and 6 laborers laid 11.2 cu. yds. of the double-ring brick lining per day, at a cost of $2 per cu. yd. All wages were as above given. It will be seen that this longer observation gave much lower costs than above tabulated, and Mr. Parmley regards it as being nearer a fair average.

Cost of a Concrete-Steel Conduit.—To Mr. G. C. Woollard, engineer for James Stewart & Co., contractors, I am indebted for the following data relating to the construction of a 6-ft. concrete-steel conduit in the Cedar Grove Reservoir, near Newark, N. J. Two conduits, side by side, were built across the bottom of the reservoir from the gate house to a tunnel outlet. Since the conduits are to be submerged, a small amount of leakage at end joints is not objectionable.

Trial sections of the conduits were tested under hydrostatic pressure; one of the conduits broke under an internal

pressure of 15 lbs. per sq. in., rupture taking place at a joint near the springing line of the arch where work had been stopped over night during construction. Another section,

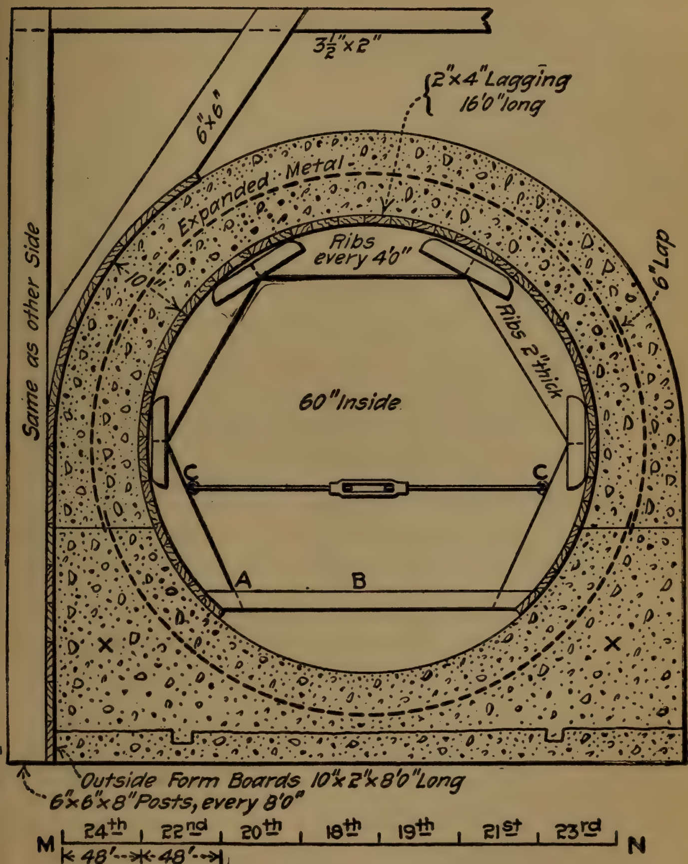


FIG. 22.

in which no stopping had occurred, resisted a pressure of 34 lbs. per sq. in.; but the leakage of the wooden bulkhead used in the test prevented applying a greater pressure.

The concrete was 1:2:5, no stone exceeding 1½ ins. being

used. Expanded metal, No. 10 steel with a 3-in. mesh, weighing 0.56 lbs. per sq. ft., made by the Associated Expanded Metal Companies, was used. When construction was begun the sheets of expanded metal were bent up into the middle wall, but it was found that the inclined part of the metal acted as a screen to separate the mortar from the stone. Hence the form of the metal was made as in Fig. 22.

"The particular thing that was insisted upon by both Mr. M. R. Sherrerd, the chief engineer of the Newark Water Department, and Mr. Carlton E. Davis, the resident engineer at Cedar Grove Reservoir, in connection with these conduits, was that they be built without sections in their circumference, that the whole of the circumference of any one section of the length should be constructed at one time. They were perfectly willing to allow us to build the conduit in any length section we desired, so long as we left an expansion joint occasionally which did not leak.

"The good construction of these conduits was demonstrated later, when the section stood 40 lbs. pressure to the square inch, and, in addition, I may say that these conduits have not leaked at all since their construction. This shows the wisdom of building the conduit all round in one piece, that is, in placing the concrete over the centers all at one time, instead of building a portion of it, and then completing that portion later, after the lower portion had had an opportunity to set.

"The centers which I designed on this work were very simple and inexpensive, as will be gathered from the cost of the work, when I state that this conduit, which measured only 0.8 cu. yd. of concrete to the lineal foot of single conduit, cost only $6.14 per cu. yd., built with Atlas cement, including all labor and forms and material, and expanded metal. The forms were built in 16 ft. lengths, each 16 ft. length having five of the segmental ribbed centers such as are shown in Fig. 22, viz., one center at each end and three intermediate centers in the length of 16 ft. These segments were made by a mill in Newark and cost 90 cts. apiece, not including the bolts. We placed the lagging on these forms at the reservoir, and it was made of ordinary 2 × 4 material, surfaced on both sides, with the edges bevelled to the radius of the circle. These pieces of 2 × 4

were nailed with two 10d. nails to each segment. The segments were held together by four ½-in. bolts, which passed through the center, and 1½-in. wooden tie block. There was no bottom segment to the circle. This was left open, and the whole form held apart by a piece, B, of 3 × 2 spruce, with a bolt at each end bolted to the lower segment on each side.

"The outside forms consisted of four steel angles to each 16 ft. of the conduit, one on each end, and two, back to back, in the middle of each 16 ft. length. These angles were 2 × 3, with the 2-in. side on the conduit, and the 3-in. side of the angle had small lugs bolted on it at intervals, to receive the 2 × 12 plank, which was slipped down on the outside of the conduit, as it was raised in height. The angles were held from kicking out at the bottom by stakes driven into the ground, and held together at the top by a ½-in. tie-rod.

"The conduit was 8 ins. thick, save at the bottom, where it was 12 ins. The reason for the 12 ins. at the bottom was that the forms had to have a firm foundation to rest on, in order to put all the weight required by the conduit on them in one day or at one time, without settling. We therefore excavated the conduit to grade the entire length, and deposited a 4-in. layer of concrete to level and grade over the entire length of the conduit line. This gave us a good, firm foundation, true and accurate to work from, and this is the secret of the good work which was done on these conduits. If you examine them, you will say that they are one of the neatest jobs of concrete in this line that has been built, especially with regard to the inside, which is true, level and absolutely smooth. [The author can confirm this statement.] When the conduit is filled with water, it falls off with absolutely no point where water stands in the conduit owing to its being out or the proper amount of concrete not being deposited.

"The centers were placed in their entirety on a new length of conduit to be built, resting upon four piles of brick, two at each end as shown. The first concrete was placed in the forms at the point marked X and the next concrete was dropped in through a trap door cut in the roof of the conduit form at the point marked Y. This material was dropped in to form the invert, and this portion was

shaped by hand with trowels and screened to the exact radius of the conduit. The concrete was then placed continuously up the sides, and boards were dropped in the angles which I have mentioned, and which served as outside form holders till the limit was reached at the top, where it was impossible to get the concrete in under the planking and thoroughly tamped. At this point the top was formed by hand and with screeds.

"Each 16-ft. length of this concrete was made with opposite ends male and female respectively, that is, we had a small form which allowed the concrete to step down at one end to 3 ins. in thickness for 8 ins. back from the end of the section, and on the other end of the section it allowed it to step down to 3 ins. in thickness in exactly the opposite way, making a scarf joint. This was not done at every 16 ft. length, unless only 16 ft. were placed in one day. We usually placed 48 ft. a day at one end of the conduit with one gang of men. This was allowed to set 24 hours, and, whatever length of conduit was undertaken in a day, was absolutely completed, rain or shine, and the gang next day resumed operations at the other end of the conduit on another 48 ft. length. This was completed, no matter what the weather conditions were, and, towards the close of this day the forms placed on the preceding day were being drawn and moved ahead.

"The method used in moving these forms ahead for another day's work is probably one of the secrets of the low cost of this work, and it is one which we have never seen employed before. The bolt at A, Fig. 22, was taken out, and the tie brace B thrown up. We had hooks at the points C. A turnbuckle was thrown in, catching these hooks, and given several sharp turns, causing the entire form to spring downward and inwards, which gave it just enough clearance to be carried forward, without doing any more striking of forms than pulling the bolt at A. This method of pulling the forms worked absolutely satisfactorily, and never gave any trouble, and we were able to move the forms very late in the day and get them all set for next day's work, giving all the concrete practically 24 hours' set, as we always started concreting in the morning at the furthest end of the form set up and at the greatest distance from the old concrete possible in the 48 ft. length, as the furthest

form had, of course, to be moved first, it being impossible to pass one form through the other.

"Six 16-ft. sections of these forms were built, and three were used each day on each end, as shown by the diagram MN, Fig. 22, which gives the day of the month for the completion of each of seven 48-ft. sections.

"A gang of men simply shifted on alternate days from end to end of the conduit, although several sections were in progress at one time; and of course, finally, when a junction was made between any division, say of 1,000 ft. to another 1,000 ft., one small form was left in at this junction inside of the conduit, and had to be taken down and taken out the entire length of the conduit.

"The centers for a 16-ft. length of this conduit cost complete for labor and material, $18.30, but they were used over and over again; and, after this conduit was completed, they were taken away for use at other points, so that the cost is hardly appreciable, and the only charge to centers that we made after the first cost of building the centers, was on account of moving them daily. Part of this conduit was built double (two 6-ft. conduits) and part single, the only difference being that, where the double conduit was built, two forms were placed side by side, and not so much was undertaken in one day.

"These conduits, when completed and dried out, rung exactly like a 60-in. cast-iron pipe, when any one walked through them or stamped on the bottom."

Mr. Woollard gives the following analysis of the cost per cubic yard of the concrete-steel conduit above described:

	Per cu. yd.
1.3 bbl. cement	$1.43
10 cu. ft. sand	0.35
25 cu. ft. stone	1.10
26 sq. ft. expanded metal, at 3 cts	0.78
Loading and hauling materials 2,000 ft. to the mixing board (team at $4.50)	0.50
Labor mixing, placing, and ramming	1.38
Labor moving forms	0.60
Total	$6.14

Wages were 17½ cts. per hr. for laborers and 50 cts. per

hr. for foremen. The concrete was 1:2:5, a barrel being assumed to be 3.8 cu. ft. The concrete was mixed by hand on platforms alongside the conduit. The cost of placing and ramming was high, on account of the expanded metal, the small space in which to tamp, and to the screeding cost. When forms were moved they were scraped and brushed with soft soap before being used again.

From Mr. Morris R. Sherrerd, Engr. and Supt., Dept. of Water, Newark, N. J., I have received the following data which differ slightly from those given by Mr. Woollard. The differences may be explained by the fact that the cost records were made at different times. Mr. Sherrerd states (Sept. 26, 1904) that each batch contains 4 cu. ft. of cement, 8 cu. ft. of sand, and 20 cu. ft. of stone, making 22 cu. ft. of concrete in place. One bag of cement is assumed to hold 1 cu. ft. He adds that a 10-hr. day's work for a gang is 63 lin. ft. of single 6-ft. conduit containing 47.4 cu. yds. of concrete and 1,260 sq. ft. of expanded metal. This is equivalent to ¾ cu. yd. of concrete per lin. ft. The total cost of material for one complete set of forms 64 ft. long was $160; and there were 7 of these sets required to keep two gangs of men busy, each gang building 63 lin. ft. of conduit a day. Since the total length of the conduit was 3,850 ft., the first cost of the material in the forms was 18 cts. per lin. ft.

Cost of Labor on 6-ft. Conduit:

	Per day.	Per cu. yd.
1 foreman on concrete	$3.35	$0.07
1 water boy	0.75	0.01
11 men mixing at $1.75	19.25	0.39
5 " mixing at $1.50	7.50	0.16
4 " loading stone at $1.40	5.60	0.12
4 " wheeling stone at $1.40	5.60	0.12
2 " loading sand at $1.40	2.80	0.06
2 " wheeling sand at $1.40	2.80	0.06
1 " placing concrete at $1.75	1.75	0.04
6 " placing concrete at $1.50	9.00	0.19
2 " supplying water at $1.50	3.00	0.06
1 " placing expanded metal at $2	2.00	0.04
1 " placing expanded metal at $1.50	1.50	0.03
Total labor on concrete	$64.90	$1.35

Cost of Labor Moving Forms:

	Per day.	Per cu. yd.
4 carpenters placing forms	$13.00	$0.27
2 helpers " "	4.00	0.08
1 carpenter putting up boards for outside forms	2.75	0.06
1 helper putting up boards for outside forms	2.25	0.05
2 helpers putting up boards for outside forms	3.50	0.07
1 team hauling lumber	4.50	0.09
1 helper hauling lumber	1.75	0.04
Total labor moving forms	$31.75	$0.66

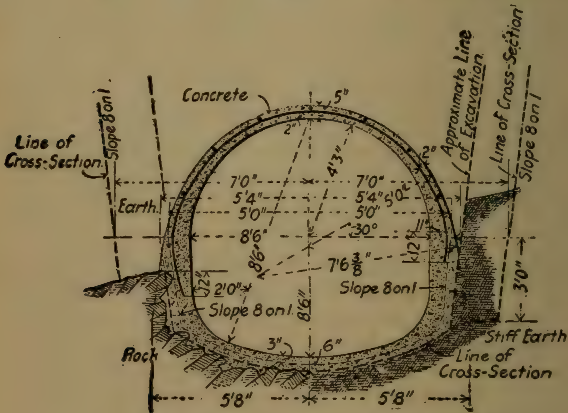
It will be noted that it required two men to bend and place the 700 lbs., or 1,260 sq. ft., of expanded metal required for 63 lin. ft. of conduit per day, which is equivalent to 5 cts. per lb., or 3 cts. per sq. ft., for the labor of shaping, placing and fastening the metal.

Concrete-steel Conduit for the Jersey City Water Supply Co.—In Engineering Record, Jan. 16, 1904, p. 72, the following data are given relating to a conduit similar to the one just described. The concrete was 1:7 of sand and trap rock ballast, 100 lbs. of cement being assumed to measure 1 cu. ft. The ballast was run of crusher, the crusher being set to break 2-in. stone. The concrete was mixed with Ransome and with Smith mixers mounted on trucks.

The concrete was mixed wet, like a thin mush, so that it would flow down on an iron trough having an 8 to 1 slope. The concrete flowed from the trough into dish-shaped shoveling boards which were on top of the arch centers, whence it was shoveled with large coal scoops into place. Forks and tamping bars were used for working the concrete against the forms so as to leave no voids. The cross-section of the conduit is shown in Fig. 23. This section was used for all depths of earth back fill up to 10 ft. Where the back fill was 15 ft. deep a heavier section, with a crown 8 ins. thick, was used. Ransome twisted rods were used for reinforcement. In no case was any difficulty experienced in keeping the reinforcing rods in their proper posi-

tions provided a little watchfulness was exercised while placing the concrete.

The centers were made in sections 12½ ft. long, consisting of 11 parts, no part weighing more than could be readily handled—200 lbs. The ⅞-in. lagging was covered with sheet steel, which was scraped clean and greased with cheap vaseline cut with kerosene oil. The sole duty of one man was to clean and grease the forms. The lagging on the bottom of the centers was omitted for a width of 6 ft., and the face of the invert was shaped by screeding and trowel-



Sections in Stiff Earth and Rock.

FIG. 23.

ing. No outside forms were employed for a width of 5 ft. over the top of the arch. The centers were supported on 6-in. cubes of concrete built into the work. Concrete was first deposited on the outside and forced under by tamping bars until it appeared on the inside. A trap-door, 2 ft. square, was left in the crown of each arch through which concrete was shoveled for the invert. After finishing the invert the walls were carried up by placing outside forms in sections 2 ft. high. At the end of each day's work a bonding groove was made in the end of the last section of concrete.

On one section for 65 working days a gang of 38 men averaged 40 lin. ft. of conduit per 10-hr. day.

Cost of Bush-Hammering Concrete.—Mr. C. R. Neher states that a concrete face can be bush-hammered by an ordinary laborer at the rate of 100 sq. ft. in 10 hrs., at a cost of 1½ cts. per sq. ft. The cost of forms saved by using rough lumber goes a long way toward covering the cost of bush-hammering. The front of the Dakota elevator in Buffalo, N. Y., was bush-hammered. Bush-hammering removes stains due to efflorescence.

Ransome says that bush-hammering concrete costs 1½ to 2½ cts. per sq. ft., wages of common laborers being 15 cts. per hr.

The walls of the Pacific Borax Co. factory at Bayonne, N. J., were dressed by hand at the rate of 100 to 200 sq. ft. per day; but most of the dressing was done with a pneumatic hammer, with which a man was able to dress 300 to 600 sq. ft. per day.

At the Harvard Stadium I timed men working with pneumatic hammers, using a tool like an ice chopper with a saw-tooth cutting blade. One man dressed a wall at the rate of 50 sq. ft. per hr., but I was told that 200 sq. ft. was a 10-hr. day's work. I am inclined to think, however, that much more than 200 sq. ft. a day could be averaged. Common laborers are used for this sort of work.

The cost of operating pneumatic hammers, when gasolene is used for power, is given in section on Bridges.

Rubble Concrete Data.—By some engineers it is believed that rubble concrete, particularly for dam construction, is a very new form of masonry. In Trans. Am. Soc. C. E., 1875, Mr. J. J. R. Croes describes work on the Boyd's Corner Dam on the Croton River, near New York. This work was begun in 1867, and for a time rubble concrete was used, but was finally discontinued, due to the impression that it might not be water-tight. In those days "sloppy" concrete would not have been allowed, which probably accounts for the difficulty of getting a water-tight rubble concrete. The specifications called for a dry concrete that had to be thoroughly rammed in between the rubble stones; and, to give room for this ramming, the contractor was not permitted to lay any two stones closer together than 12 ins. As a result, not more than 33% of

the masonry was rubble stones, the rest being the concrete between the stones. Mr. Croes states that most of the bidders erred in assuming that 66% to 75% of the masonry would be rubble stones.

In an editorial article in Engineering News, July 16, 1903, I have discussed some features of rubble concrete construction, which it may be well to summarize here. In the first place, the form of the rubble stones as they come from the quarry should be considered. Stones that have flat beds, like many sandstones and limestones, can be laid upon layers of "dry" concrete, and can have their vertical joints readily filled with concrete rammed into place. But granites and other stones that break out irregularly, can not be well bedded in concrete unless it is made so soft as to be "sloppy." In thin retaining walls, small, irregular stones may be forced into concrete by jumping upon them, men wearing rubber boots.

When stones come out flat bedded, if it is desired to economize cement, make the bed joints of ordinary mortar (not concrete), and fill the vertical joints with concrete.

Generally it is an absurd practice to break up large blocks of stone in a crusher for the purpose of making the whole of a heavy wall of concrete, since rubble concrete requires not only less cement but effects a saving in crushing. There are exceptions, however. For example, the anchorages of the Manhattan Bridge in New York City are specified to be of rubble concrete, doubtless because the designer believes this sort of masonry to be cheaper than concrete. In this case an economic mistake has been made, for all the rubble stone must be quarried up the Hudson River, loaded into scows, unloaded onto cars, and finally unloaded and delivered by derricks. Now this repeated handling of large, irregular rubble stones is so expensive that it more than offsets the cost of crushing, as well as the extra cost of cement in plain concrete. Crushed stone can be unloaded from boats by means of clam-shell dredge buckets at a low cost. It can be transported on a belt conveyor, elevated in a bucket conveyor, mixed with sand and cement, and delivered to the work, all with very little

manual labor where the installation of a very efficient plant is justified by the magnitude of the job. Large rubble stones, on the other hand, can not be handled so cheaply nor with as great rapidity as crushed stone. Each particular piece of work, therefore, must be treated as a separate problem in engineering economics; for no unqualified generalization as to the relative cheapness of this or that kind of masonry is to be relied upon.

In Engineering Record, Aug. 8, 1903, the construction of the Boonton Dam, Boonton, N. J., is described. The dam is of cyclopean masonry, that is, of large rubble stones bedded in concrete. The concrete was made so wet that when the stones were dropped into it the concrete flowed into every crevice. The granite rubble stones measured from 1 to 2½ cu. yds. each. It is estimated that only 40 to 45% of the dam is concrete, the rest being rubble. The materials were all delivered on cars, from which they were delivered to the dam by derricks provided with bull-wheels. On the dam were 4 laborers and 1 mason to each derrick, and this gang dumped concrete and joggled the rubble stones into it. A derrick has laid as much as 125 cu. yds. of masonry in 10 hrs. With 35 derricks, 20 of which were laying masonry and 15 either passing materials to the other derricks, or being moved, as much as 21,000 cu. yds. of masonry were laid in one month. The amount of cement per cubic yard of masonry is variously stated to have been 0.6 to 0.75 bbl.

In the construction of a dry dock at the Charleston Navy Yard, rubble concrete was used. The rubble stones averaged about ½ cu. yd. each, and were spaced about 18 ins. apart. About 67% of the masonry was 1:2:5 concrete, leaving 33% of rubble stones.

In Engineering News, June 18, 1903, the Spier Falls Dam, on the upper Hudson River, is described. This dam is of cyclopean masonry, the rubble stones being very large pieces of granite, which are bedded in 1:2½:5 concrete. At the time of my visit to the dam, it was estimated that about 33% of the masonry was concrete. I have recently been informed by Mr. C. E. Parsons, the chief engineer, that about 1 bbl. of cement was used in each cubic yard of ma-

sonry. This high percentage of cement may be accounted for by the fact that there was a good deal of plain rubble laid in cement mortar, no accurate record of which was kept. At the time of my visit, three Ransome mixers were being used, two for concrete and one for mortar. Each concrete mixer averaged 200 batches in 10 hours, of 23 cu. ft. of concrete per batch. I am inclined to think, from inspection of the masonry during the time it was being laid, that about 40% of the dam was rubble stones, and the remaining 60% was concrete and mortar. The stones and concrete were delivered by cableways to stiff-leg derricks, which deposited the material in the dam. There were two laborers to each mason employed in placing the materials, wages being 15 cts. and 35 cts. per hr. respectively. The labor cost of placing the materials was 60 cts. per cu. yd. of masonry.

In Engineering News, July 7, 1904, a rubble concrete dam across the Chattahoochee, 17 miles north of Atlanta, Ga., is described and illustrated. The stone was a local gneiss that came out of the quarry in large slabs with parallel beds, some stones containing 4 cu. yds. each. About 40% of the dam was of this rubble and 60% of concrete between the rubble stones. The concrete was a 1:2½:5 mixture.

In Engineering News, Jan. 21, 1897, a description is given of the breakwater at Marquette, Mich., which was built of rubble concrete, the rubble stones amounting to 27% of the volume of the breakwater masonry.

The Hemet Dam, California, is built of granite rubble concrete, the concrete being a 1:3:6 mixture. The face stones of the dam were laid in mortar. There were 31,100 cu. yds. of masonry, which required 20,000 bbls. of cement, or 0.64 bbl. per cu. yd. The cement was hauled 23 miles over roads having grades of 18% in places, the total ascent being 3,350 ft. The cost of hauling was $1 to $1.50 per bbl. The sand was conveyed 400 ft. from the river to the dam by an endless double-rope carrier provided with V-shaped buckets spaced 20 ft. apart, the rise of the conveyor being 125 ft. in the 400 ft. This was a simple and inexpensive conveyor.

Some English Data on Rubble Concrete.—The following is an abstract of an article from London "Engineering": Railway work, under Mr. John Strain, in Scotland and Spain, involved the building of abutments, piers and arches of rubble concrete. The concrete was made of 1 part cement to 5 parts of ballast, the ballast consisting of broken stone or slag and sand mixed in proportions determined by experiment. The materials were mixed by turning with shovels 4 times dry, then 4 times more during the addition of water through a rose nozzle. A bed of concrete 6 ins. thick was first laid, and on this a layer of rubble stones, no two stones being nearer together than 3 ins., nor nearer the forms than 3 ins. The stones were rammed and probed around with a trowel to leave no spaces. Over each layer of rubble, concrete was spread to a depth of 6 ins. The forms or molds for piers for a viaduct were simply large open boxes, the four sides of which could be taken apart. The depth of the boxes was uniform, and they were numbered from the top down, so that, knowing the height of a given pier, the proper box for the base could be selected. As each box was filled, the next one smaller in size was swung into place with a derrick. The following bridge piers for the Tharsis & Calanas Ry. were built:

Name.	Length of Bridge. Ft.	Height of Piers. Ft.	No. of Spans.	Cu. Yds. in Piers.	Weeks to Build.
Tamujoso River....	435	28	12	1,737	14½
Oraque...............	423	31	11	1,590	15
Cascabelero.........	480	30 to 80	10	2,680	21
No. 16...............	294	28 to 50	7	1,046	16¼
Tiesa.................	165	16 to 23	8	420	4

It is stated that the construction of some of these piers in ordinary masonry would have taken four times as long. The rock available for rubble did not yield large blocks, consequently the percentage of pure concrete in the piers was large, averaging 70%. In one case, where the stones were smaller than usual, the percentage of concrete was 76½%. In other work the percentage has been as low as 55%, and in still other work where a rubble face work was used the percentage of concrete has been 40%.

In these piers the average quantities of materials per cubic yard of rubble concrete were:

448 lbs. (0.178 cu. yd.) cement.
0.36 cu. yd. sand.
0.68 cu. yd. broken stone (measured loose in piles).
0.30 cu. yd. rubble (measured solid).

Several railway bridge piers and abutments in Scotland are cited. In one of these, large rubble stones of irregular size and weighing 2 tons each were set inside the forms, 3 ins. away from the plank and 3 ins. from one another. The gang to each derrick was: 1 derrickman and 1 boy, 1 mason and 10 laborers, and about one-quarter of the time of 1 carpenter and his helper raising the forms. For bridges of 400 cu. yds., the progress was 12 to 15 cu. yds. a day. The forms were left in place 10 days.

To chip off a few inches from the face of a concrete abutment that was too far out, required the work of 1 quarryman 5 days per cu. yd. of solid concrete chipped off.

Concrete was used for a skew arch over the River Dochart, on the Killin Ry., Scotland. There were 5 arches, each of 30 ft. span on the square or 42 ft. on the skew, the skew being 45°. The piers were of rubble concrete. The concrete in the arch was wheeled 300 ft. on a trestle and dumped onto the centers. It was rammed in 6-in. layers, which were laid corresponding to the courses of arch stones. As the layers approached the crown of the arch, some difficulty was experienced in keeping the surfaces perpendicular. Each arch was completed in a day.

In a paper by John W. Steven, in Proc. Inst. C. E., the following is given:

	Concrete per cu. yd.	Rubble Concrete per cu. yd.	Per Cent. of Rubble in Rubble Concrete.
Ardrossan Harbor........	$6.00	$5.00	20.0
Irvine Branch............	7.00	3.68	63.6
Calanas & Tharsis Ry....	7.08	3.43	30.3

Cost of a Rubble Concrete Abutment.—Mr. Emmet Steece gives the cost of 278 cu. yds. rubble concrete in a bridge abutment at Burlington, Ia., as follows:

	Per cu. yd.
0.82 bbl. Saylor's Portland, at $2.60	$2.14
0.22 cu. yd. sand, at $1	0.22
0.52 cu. yd. broken stone, at $0.94	0.49
0.38 cu. yd. rubble stones, at $0.63	0.24
Water	0.07
Labor (15 cts. per hr.)	1.19
Foreman	0.09
Total	$4.44

The concrete was 1:2½:4½, laid in 4-in. layers, on which were laid large rubble stones spaced about 6 ins. apart. Concrete was rammed into the spaces between the rubble, which was then covered with another 4-in. layer of concrete, and so on. A force of 28 men and a foreman averaged nearly 40 cu. yds. of rubble concrete per day. The cost of lumber for the forms is not included. The abutment was 3 ft. wide at top, 9 ft. at the base and 30 ft. high.

Cost of Removing Efflorescence With Acid.—Efflorescence, or "whitewash," on a concrete bridge at Washington, D. C., was removed by using hydrochloric (muriatic) acid and common scrubbing brushes; 30 gals. of acid and 36 scrubbing brushes were used to clean 250 sq. yds. of concrete. The acid was diluted with 4 or 5 parts water to 1 of acid; and water constantly played with a hose on the concrete while being cleaned to prevent penetration of the acid. One house-front cleaner and 5 laborers were employed, and the total cost was $150, or 60 cts. per sq. yd. This high cost was due to the difficulty of cleaning the balustrades. It is thought that the cost of cleaning the spandrels and wing walls did not exceed 20 cts. per sq. yd. The cleaning was perfectly satisfactory. An experiment was made with wire brushes without acid, but the cost was $2.40 per sq. yd. The flour removed by the wire brushes was found by analysis to be silicate of lime. Acetic acid was tried in place of muriatic, but required more scrubbing.

Cost of Sylvester Wash and Sylvester Mortar.—Mr. W. C. Hawley is authority for the following: A covered con-

crete clear water well of the Apollo Water-Works Co. leaked, so it was plastered with a Sylvester mortar. A light colored soft soap was dissolved in water, 1¼ lbs. soap to 15 gallons of water. Then 3 lbs. of powdered alum were mixed with each bag of cement. The mortar was 1:2. Two coats of this plaster were applied to the dry walls, giving a total thickness of ½ in. Leaking was thus stopped completely.

The cost was:

2 lbs. soap (with 24 gals. water), at 7½ cts.	$0.15
12 lbs. alum, at 3½ cts.	0.42
Total	$0.57

Or 57 cts. for soap and alum per barrel of Portland cement.

In repairing the bottom of a reservoir lined with 4 to 6 ins. of concrete which leaked, a Sylvester wash was used. The soap solution was ¾ lb. of Olean soap to 1 gal. of water, and the alum solution was ½ lb. alum to 4 gals. water; both well dissolved, soap solution being boiled. On the clean dry concrete the boiling hot soap solution was applied; 24 hrs. later the alum wash; 24 hrs. later the soap wash; 24 hrs. later the alum wash. Two men applied the solutions, using whitewash brushes, while a third man carried pails of the solution. In making the soap solution 2 men attended 4 kettles, 1 man kept up fires, 2 men carried solution to men applying it. The alum solution required fewer men, being made cold in barrels. After applying the second soap wash to the concrete slopes, men had to be held by ropes to keep from slipping. The rope was placed around two men, who started work at top of the slope, a third man paying out on the rope. The work was done in 8½ days, and the cost as follows:

Labor:

1,140 hrs. labor at 15 cts.	$171.00
83 " foremen at 30 cts.	24.90
83 " waterboy at 6 cts.	4.98
Add for supt. 15%	30.13
Total labor	$231.01

Materials:

900 lbs. Olean soap at 4 1-3 cts.	$39.00
210 " alum at 3 cts.	6.30
6 whitewash brushes (10-in), at $2.25	13.50
6 stable brushes, $1.25	7.50
Total materials	$66.30
Total labor and materials	$297.31

This covered 131,634 sq. ft., hence the cost of the two coats of soap and alum was $2.26 per 1,000 sq. ft., or 0.23 ct. per sq. ft. All leaks but one from a slight crack were stopped.

The concrete lining of a new reservoir near Wilmerding was waterproofed by using caustic potash and alum in the finishing mortar coat. The stock solution was 2 lbs. of caustic potash, and 5 lbs. of alum to 10 qts. of water. This was made in barrel lots, from which 3 qts. were taken for each batch of finishing mortar, which consisted of 2 bags of cement mixed with 4 bags of sand; a batch of mortar covered an area 6 ft. × 8 ft. × 1 in. thick. The extra cost of this waterproofing was:

100 lbs. caustic potash at 10 cts.	$10.00
70 " caustic potash at 9 cts.	6.30
960 " alum at 3¼, 3¾ and 4 cts.	34.38
60 hrs. mixing at 15 cts.	9.00
Fr't, express and hauling	11.50
Total for 74,800 sq. ft.	$71.18

So the cost was 95 cts. per 1,000 sq. ft., or less than 0.1 ct. per sq. ft. Hence the cost was less than by using Sylvester's wash and the result was better, for with Sylvester's wash the penetration is only 1-16 to ⅛-in. It was found that if less than 2 parts of sand to 1 part of cement were used the mortar cracked in setting. Clean sand was imperative as any organic impurities soon decomposed, leaving soft spots. Do not use an excess of potash; a slight excess of alum, however, does not decrease the strength of the mortar.

SECTION VII.

COST OF WATER-WORKS.

Cost of Loading and Hauling Cast Iron Pipe.—Three men assisted by a driver averaged 5 lengths of 12-in. pipe loaded from a flat car onto a wagon in 12 mins. Planks were laid from the car to the wagon and the pipe was rolled down the plank runway. This same gang would unload a wagon in 6 mins. As each length of pipe weighed nearly ½ short ton, the wagon load was 2½ tons. It, therefore, cost 5 cts. per ton to load and 2½ cts. per ton to unload the wagons, wages of men being 15 cts. per hr.; but this does not include the lost time of the two horses during loading and unloading, which is equivalent to about 2 cts. per ton. The total fixed cost of loading and unloading was 10 cts. per ton, including team time. The hauling costs 12 cts. per ton per mile, where 2½ tons are the load (wages of team and driver 35 cts. per hr.), and the team returns empty. Good, hard, level roads are required for so large a load. See page 76 for discussion of teaming. If the haul is short and this loading gang of 3 men walks along with the wagon, the cost of hauling becomes 25 cts. per ton mile, instead of 10 cts.

Pipe should never be shipped in hopper-bottom cars, for the difficulty of unloading adds very much to the cost. I have had a gang of 6 men who unloaded only 75 lengths of 12-in. pipe in 10 hrs. from a hopper gondola, into wagons. Each length weighed 800 lbs., making 30 tons the day's work, at 30 cts. per ton. This work was by hand, no derrick being available.

Prices of Cast Iron Pipe Since 1882.—Figure 24 shows the prices paid for cast iron pipe in cities and towns of the Central West, centering about Chicago, according to data collected by J. W. Alvord from pipe contracts as published in Engineering News.

Weight of Cast Iron Pipe.—Pipe from 3 ins. to 60 ins. diameter is cast in 12-ft. lengths, that is in lengths that require 440 pipe lengths to lay a mile of pipe line; 1½-in. and 2-in. pipes are not often used, but when used are cast in shorter lengths.

Table XVII gives the approximate weights of cast iron

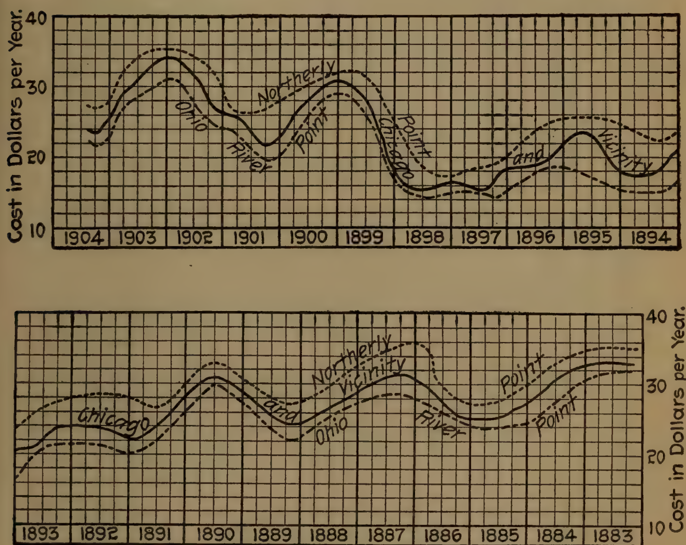


FIG. 24.

pipes. It is customary to paint the weight of each pipe inside the pipe. As variations in single pipes of 5% from the listed weight are common, it is well to specify the maximum average variation allowable.

Water Pipe Trenches.—Trenches for water pipes in the northern part of America are usually 5 ft. deep from the surface of the street to the axis of the pipe. In the South, trenches are only 3 ft. deep. Water-pipe trenches are usually dug not less than 18 to 24 ins. wider than the inside diameter of the pipe; and just before the pipes are laid a gang of men enlarges and deepens the trench for a

TABLE XVII.—Weight of Cast Iron Pipe.

Inside Diam. of Pipe, in inches.	Head, 100 ft. Pressure, 43 lbs.			Head, 200 ft. Pressure, 86 lbs.			Head, 300 ft. Pressure, 180 lbs.			Head, 400 ft. Pressure, 173 lbs.			Lead per joint, Lbs.	Hemp per joint, Lbs.	Inside Diam. of Pipe, in inches.
	Thickness,	Weight, lbs. per		Thickness,	Weight, lbs. per		Thickness,	Weight, lbs. per		Thickness.	Weight, lbs. per				
	Ins.	Foot.	Length	Ins.	Foot.	Length	Ins.	Foot.	Length	Ins.	Foot.	Length			
3	.38	13.9	167	.42	15.4	185	.45	16.7	200	.45	16.7	200	4.4	.18	3
4	.40	19.2	230	.42	20.3	243	.45	21.7	260	.47	22.1	265	5.5	.21	4
5	.42	24.6	295	.45	26.3	315	.48	28.2	338	.51	29.6	355	6.8	.27	5
6	.48	30.4	364	.47	32.8	393	.51	35.5	426	.54	37.1	445	8.0	.31	6
8	.47	42.8	513	.51	47.3	567	.56	52.0	624	.61	55.4	665	11.5	.44	8
10	.50	57.1	685	.56	63.8	765	.62	71.0	852	.68	76.7	920	14.5	.53	10
12	.53	72.5	870	.60	82.1	985	.68	92.5	1110	.75	100.8	1210	18.0	.61	12
14	.56	89.5	1074	.65	102.4	1229	.73	116.6	1399	.82	128.3	1540	21.5	.81	14
16	.60	107.8	1293	.69	124.7	1496	.79	143.6	1723	.89	158.3	1900	24.0	.94	16
18	.63	127.7	1532	.74	149.0	1788	.85	172.1	2065	.96	191.7	2300	27.0	1.00	18
20	.66	149.0	1788	.78	175.3	2104	.91	203.7	2444	1.03	228.3	2740	31.5	1.25	20
24	.75	200.6	2407	.87	233.6	2803	1.02	274.9	3299	1.16	306.7	3680	37.0	1.50	24
30	.87	290.2	3482	1.01	356.6	4027	1.19	398.6	4783	1.37	451.7	5420	51.0	2.06	30
36	.98	391.6	4699	1.14	455.0	5460	1.36	545.3	6543	1.58	624.2	7490	75.0	3.00	36
40	1.09	483.9	5807	1.23	543.8	6525	1.48	654.8	7858	1.72	754.2	9050	85.0	3.37	40
42	1.10	512.3	6147	1.28	591.7	7100	1.54	713.6	8563	1.79	824.2	9890	90.0	3.62	42
48	1.25	665.2	7982	1.41	745.5	8946	1.71	904.8	10857	1.99	1045.8	12550	110.0	4.37	48
60	1.40	916.7	11000	1.68	1105.0	13260	2.05	1336.7	16040	2.41	1580.8	18970	150.0	6.25	60

short space where each pipe joint is to come; this is called digging the "bell-holes." The bell-holes enable the yarners calkers to make the joints properly. It is usually not necessary to brace the sides of a trench that is only 5 or 6 ft. deep.

Cost of Trenching.—At Corning, N. Y., a trench for a 10-in. water pipe was excavated 2½ ft. wide × 5 ft. deep, × 1,500 ft. long = 600 cu. yds. in 4½ days by 24 men, or at the rate of 6 cu. yds. per man per 10-hr. day, equivalent to 11 cts. a running foot or 25 cts. a cu. yd. The backfilling was done in 3 days by 2 men and 1 horse with driver, using a drag scraper and a short length of rope so that the horse worked on one side of the trench while the two men handled the scraper on the opposite side, pulling the scraper directly across the pile of earth. In this way the backfilling was made at a cost of 1.1 cts. per lin. ft. or 2½ cts. per cu. yd., there being no ramming of the backfill required. This is a remarkably low cost for backfilling, and one not ordinarily to be counted upon. The material was a loamy sand and gravel.

At Rochester, N. Y., with the size of trench and kind of material practically the same as above:

1 man excavated 8 cu. yds. a day at cost of 19 cts. per cu. yd.

1 man backfilled 16 cu. yds. a day at cost of 9 cts. per cu. yd.

Total cost of excavation and backfill, 28 cts. per cu. yd.

Cost of Trenching, Great Falls, Mont.—The Great Falls (Montana) Water Co. excavated 25,500 cu. yds. of earth, 1,900 cu. yds. of loose rock, and 1,500 cu. yds. of solid rock, in trenching for a 6-in. water pipe. The work was done by company labor (not by contract), wages being $2.25 for laborers, and the cost was 34 cts. per cu. yd. for excavation and 3½ cts. more per cu. yd. for backfilling and tamping. If wages had been $1.50 a day the cost would have been 23 cts. per cu. yd. for excavation and 2½ cts. per cu. yd. for backfilling.

Cost of Trenching, Astoria, Oregon.—Mr. A. L. Adams, states that in trenching for the Astoria (Oregon) Water-

works, in 1896, the first contractor averaged only 7 to 8 cu. yds. per man per day. Later on another contractor, even in the rainy season, averaged nearly 10 cu. yds. per man per 10-hr. day of trenching (including backfilling), at a cost (including foreman) of 17¼ cts per cu. yd., wages being $1.70 a day. The material was yellow clay dug with mattocks and shovels.

Cost of Trenching, Hilburn, N. Y.—Mr. W. C. Foster gives the following data on 17,000 ft. of trenching for water pipe at Hilburn, N. Y. The trench was 4 ft. deep, for 4-in. to 8-in. pipe. The digging was hard, the banks being full of cobbles and frequently caved in. The streets were not paved. The cost of trenching and backfilling was 10.1 cts. per lin. ft., wages being $1.35 for laborers and $3 for foremen.

Cost of Trenching and Pipe Laying, Providence, R. I.—In Engineering News, June 28, 1890, Mr. E. B. Weston, Engineer Water Department, Providence, R. I., gives very full records of pipe laying costs. The following tables are given by him, and are based upon many miles of trench work:

EASY DIGGING, SAND.

Size of pipe, ins	4	6	8	10	12	16	20
1. Trenching*	.0422	.0518	.0611	.0707	.0798	.1445	.2088
2. Laying	.0129	.0162	.0191	.0219	.0249	.0370	.0497
3. Foreman	.0130	.0158	.0188	.0216	.0244	.0303	.0360
4. Tools, etc	.0041	.0050	.0059	.0069	.0078	.0134	.0191
5. Calking	.0106	.0107	.0108	.0111	.0118	.0159	.0301
6. Lead, 5 cts. lb	.0224	.0320	.0431	.0553	.0683	.0950	.1203
7. Teams	.0070	.0090	.0115	.0136	.0160	.0203	.0216
8. Carting	.0078	.0149	.0208	.0275	.0346	.0518	.0746
9. Total	.1200	.1554	.1911	.2286	.2676	.4082	.5602

MEDIUM DIGGING, GRAVEL, ETC.

Size of pipe, in.	4	6	8	10	12	16	20	24
1. Trenching*	.0597	.0697	.0790	.0883	.0974	1700	.2400	.3019
2 Laying	.0189	.0220	.0249	.0279	.0307	.0440	.0577	.0639
3. Foreman	.0180	.0203	.0234	.0265	.0294	.0350	,0373	.0396
4. Tools, etc.	.0056	.0065	.0075	.0084	.0093	.0154	.0214	.0602
5. Calking	.0106	.0107	.0108	.0111	.0118	.0159	.0301	.0757
6. Lead 5c. lb	.0224	.0320	.0431	.0553	.0683	.0950	.1203	.1600
7. Teams	.0070	.0090	.0115	.0136	.0160	.0203	.0216	.0228
8. Carting	.0078	.0149	.0208	.0275	.0346	.0518	.0746	.1317
9. Total	.1500	.1854	.2210	.2586	.2975	.4474	.6030	.8630

*Including backfilling, and in all cases the depth of the trench was such that the center of the pipe was 4 ft. 8 ins. below ground surface.

HARD DIGGING, HARD OR MOIST CLAY.

Size of pipe, ins.	4	6	8	10	12	16	20
1. Trenching*	.0860	.0959	.1053	.1147	.1300	.2261	.3264
2. Laying	.0271	.0303	.0333	.0362	.0411	.0530	.0669
3. Foreman	.0260	.0286	.0314	.0343	.0372	.0428	.0452
4. Tools, etc	.0081	.0090	.0099	.0109	.0118	.0201	.0283
5. Calking	.0106	.0107	.0108	.0111	.0118	.0159	.0301
6. Lead, 5 cts. lb.	.0224	.0320	.0431	.0553	.0683	.0950	.1203
7. Teams	.0070	.0090	.0115	.0136	.0160	.0203	.0216
8. Carting	.0078	.0149	.0208	.0275	.0346	.0513	.0746
9. Total	.1950	.2304	.2661	.3036	.3508	.5250	.7134

*Including backfilling, and in all cases the depth of the trench was such that the center of the pipe was 4 ft. 8 ins. below ground surface.

Wages in all cases above were $1.50 a day for laborers trenching and laying, $3 a day for foreman, $2.25 for calkers, and $2.25 for teams which probably refers to team without driver. Carting was in all cases $1 a ton. Allowance for tools, item 4, was made on a basis of 7.2% of items 1 and 2.

Tap and stop		Lead service pipe per lin. ft.		
Diam. in ins.	Tap, stop, etc. including tapping.	Diam. in ins.	Weight in lbs.	Cost of pipe trenching laying, etc.
3/8	$6.00	1/2	3.00	$0.34
1/2	6.23	5/8	4.00	.40
5/8	6.81	3/4	4.75	.45
3/4	8.67	1	6.00	.52
1	10.71	1 1/4	9.00	.70
....	.....	1 1/2	10.00	.76

In the above, lead pipe was assumed at 6 cts. per lb.; labor of trenching and laying, 16 cts. per ft.

Short lengths, 15 to 50 ft., of 6-in. pipe cost 34 cts. per ft. in easy digging to 45 cts. in hard digging for excavation, laying and backfilling, wages being as above stated.

The trench for a 24-in. pipe, 19,416 ft. long and 6.6 ft. deep cost 32 cts. per cu. yd. for excavation and backfill, with wages at $1.50 a day.

A 48-in. main was laid for $1.65 per ft. including digging, laying, calking and backfilling.

A 16-in. pipe, 374 ft. long passed under two railway tracks, and the cost of trenching, laying and backfilling was 50 cts. per ft.

An 8-in. pipe was laid across a bridge, and the cost of boxing, laying pipe, etc., was $1.32 per ft., while for a 12-in. pipe the cost was $1.50 per ft.

TABLE XVIII.—Cost of Pipe and Laying per Linear Foot.

Size of Pipe. Inches.	Weight per length. Pounds.	Weight per linear foot. Tons. (2,000 lbs.)	Cost @ $30.00 per ton.	Teaming, 30c. per ton mile. Haul 2½ miles.	Lead. 5c. per pound.	Miscellaneous expenses.	Labor.	Total cost.
12 *A	810	0.034	$1.02	$0.025	$0.100	$0.065	$0.45	$1.66
*E	1,040	0.043	1.29	0.035	0.100	0.065	0.46	1.95
14 A	1,010	0.042	1.26	0.030	0.120	0.070	0.46	1.94
E	1,310	0.055	1.65	0.040	0.120	0.070	0.47	2.35
16 A	1,215	0.051	1.53	0.040	0.130	0.070	0.50	2.27
E	1,610	0.067	2.01	0.050	0.130	0.070	0.51	2.77
18 A	1,400	0.058	1.74	0.040	0.150	0.080	0.56	2.57
E	1,910	0.080	2.40	0.060	0.150	0.080	0.58	3.27
20 A	1,610	0.067	2.01	0.050	0.180	0.090	0.61	2.94
E	2,260	0.094	2.82	0.070	0.180	0.090	0.64	3.80
24 A	2,050	0.085	2.55	0.060	0.200	0.110	0.70	3.62
E	3,000	0.125	3.75	0.090	0.200	0.110	0.73	4.88
30 A	2,860	0.119	3.27	0.090	0.250	0.130	0.78	4.52
E	4,340	0.181	5.43	0.135	0.250	0.135	0.83	6.78
33 A	3.800	0.158	4.74	0.120	0.300	0.140	0.88	6.18
E	5.900	0.246	7.08	0.185	0.300	0.145	0.93	8.64
42 A	4,920	0.205	6.15	0.155	0.350	0.175	1.02	7.85
E	7,720	0.322	9.66	0.240	0.350	0.180	1.12	11.55
48 A	6,130	0.256	7.68	0.190	0.400	0.240	1.47	9.98
E	9,740	0.407	12.21	0.305	0.400	0.245	1.57	15.73
54 A	7,510	0.312	9.36	0.235	0.450	0.275	1.66	11.98
E	12,400	0.516	15.48	0.390	0.450	0.280	1.76	18.36
60 A	8,900	0.370	11.10	0.275	0.500	0.325	1.96	14.41
E	15,100	0.628	18.84	0.470	0.500	0.330	2.12	23.27

*A is light-weight pipe. E is heavy-weight pipe.

Trenches were ordinarily 2 ft. wider than the pipe and 5 ft. plus half the diameter of the pipe deep. Such trenches were dug, the pipe laid and backfilling made at the following rate per laborer engaged:

6-in. pipe,	easy earth	21.0	lin. ft. per day
6-in. "	medium earth	17.2	" "
6-in. "	hard earth	10.3	" "
8-in. "	easy earth	19.3	" "
12-in. "	medium earth	13.4	" "
20-in. "	easy earth	9.0	" "
24-in. "	medium earth	4.4	" "

Earth excavation in trenches where digging is easy costs 20 cts. per cu. yd.; rock excavation averages $2 per cu. yd. and runs as high as $3, wages being $1.50 a day for labor.

Cost of Water Pipes Laid at Boston.—Mr. C. M. Saville gives the following data relative to 62 miles of pipe work done by contract for the City of Boston: The costs are averages of the actual costs under 21 contracts, from 1896 to 1903. As a general rule the pipes were laid with the axis of the pipe 5 ft. below the surface. The pipes were usually placed in the trench by a hand operated derrick spanning the trench. In practically all cases the streets were macadamized. Just how many feet of each kind of pipe were laid is not stated; but there were not less than the following amounts:

12-in. pipe	15,500 ft.
16-in. pipe	44,600 ft.
20-in. pipe	21,200 ft.
24-in. pipe	19,600 ft.
30-in. pipe	7,200 ft.
36-in. pipe	36,800 ft.
48-in. pipe	97,900 ft.

The first item in Table XVIII of $30 per ton for pipe was calculated by adding 12% to the actual cost of $26.80 per ton, this 12% being added to cover incidentals. These incidentals are as follows, by percentages:

	Per cent.
Small pipes for blow-offs and connections	1½
Special castings	4½

Valves	5
Miscellaneous materials	1
Total percentage to be added to the cost per short ton of straight pipe	12

The cost of teaming on 21 contracts previous to 1898 was 26 cts. per ton per mile, the average haul being 2.4 miles from the pipe yards; but, in order to be liberal, 30 cts. per ton per mile for a 2½-mile haul is assumed as an average; wages of two-horse team and driver being 45 cts. per hr.

The lead is estimated at 5 cts. per lb., and as each joint requires about as many pounds of lead as 2 times the diameter of the pipe in inches, the cost of lead per foot of pipe is found by

$$\frac{2 \times \text{diam. of pipe in ins.}}{12} \times \$0.05.$$

The column headed "miscellaneous expenses" is based upon actual experience, and includes cost of tools, insurance of men, lumber, yarn, and incidental expenses. The tools depreciate about 50% on any contract. It was estimated that 4% of the cost of laying the pipe should be added to cover the cost of tools. The cost of accident insurance was 3% of the pay roll. The contractor's bond cost ½% of the bond. Incidental expenses were about 1% of the pay roll. It was estimated that these three items amounted to 3.2% of the cost of laying the pipe. The cost of lumber, yarn, etc., averaged 2.8% of the cost of hauling and laying. Hence, the total cost of "miscellaneous expenses" was 4% + 3.2% + 2.8%, which is 10% of the cost of laying the pipe. The word "laying" is here used to include the cost of hauling the pipe, the cost of lead, the cost of trenching and backfilling, and the cost of placing the pipe in the trench and calking it.

The column headed "labor" includes the cost of trenching in earth (there was very little rock), and the cost of placing the pipe in the trench and calking it. Wages paid for labor were as follows:

Foreman..	$100.00 per month
Sub-foreman..	3.00 per day
Calkers and yarners	2.50 "
Laborers, 1st class	1.75 "
" 2d "	1.60 "
Double team and driver	0.45 per hour
Single " "	0.30 "

A considerable amount of extra work was done by force account on 38 miles of the pipe lines, averaging 12 cts. per ft. of line, due to obstructions encountered causing changes of location, etc.

Cost of Water Pipe Laid at Alliance, O.—Mr. L. L. Tribus gives the following costs of work done in 1894, the material being loam and clay excavated to such a depth that 4 ft. of earth would be left on top of each class of pipe after backfilling:

Size of pipe in ins	4	6	8	10	12
Wt. of pipe, lbs. per ft	19	30¼	44	62	79
Lbs. special per ft	0.4	0.76	1.1	1.55	1.9
Lbs. lead per ft	0.4	0.66	1.0	1.25	1.5
Lbs. yarn per ft	0.02	0.025	0.05	0.08	0.1
Total length in ft	2,890	9,760	1,860	3,320	2,930

COST PER LIN. FT. LAID.

Size of pipe, ins	4	6	8	10	12
Pipe	$0.2360	$0.3780	$0.5350	$0.7470	$0.9400
Specials and valves	.0120	.0189	.0268	.0374	.0470
Hauling	.0056	.0078	.0011	.0145	.0190
Lead	.0020	.0330	.0500	.0630	.0750
Yarn	.0014	.0018	.0035	.0056	.0070
Trenching	.1240	.1210	.1287	.1480	.1902
Pipe laying	.0370	.0346	.0313	.0542	.0463
Total	$0.4360	$0.5951	$0.7764	$1.0697	$1.3245

This work was done by laborers and men employed by the water company and does not include cost of superintendence. The 4-ft. cover over the pipe was in some cases exceeded. The digging was comparatively easy with little ground water to bother. Mr. Tribus informs me that the wages paid were: Laborers, $1.25; pipe handlers, $1.50; and calkers, $2.25, per 10-hour day.

Cost of Water Pipe Laid at Porterville, Cal.—Mr. P. E. Harroun gives the following data on laying 4, 6, 8 and 10-in. water pipe and making service connections, at Porterville, Cal., in 1904. The work was done by company labor, and the workmen were very inefficient. All trenches

were 1½ ft. wide and 3⅓ ft. deep in a heavy adobe (clay), except for short stretches in sand as hereafter noted. The streets were not paved, but covered with 4 ins. of hard rolled clay and gravel which required a 4-horse plow to break through. In backfilling, a "go devil" was used to throw the material into the trench wherever practicable, and water from street hydrants was used to consolidate the backfill.

Cost of 4-in. water pipe line (2,846 ft. long, of which 900 ft. were in sand):

	Per ft.
Labor trenching, at 20 cts. per hr.	$0.070
Two horses trenching, at 15 cts. per hr.	0.001
Labor digging bell-holes, at 20 cts. per hr.	0.015
Labor laying pipe, at 20 cts. per hr	0.010
Yarners, at 22½ cts. per hr.	0.005
Labor pouring lead, at 20 cts per hr.	0.004
Calkers, at 25 cts. per hr.	0.008
Labor backfilling, at 20 cts. per hr	0.011
Two horses backfilling, at 15 cts. per hr	0.004
Distribution of materials, at 60 cts. per ton	0.005
Miscellaneous labor	0.004
Foreman, at 40 cts. per hr.	0.017
Time keeper	0.002
Total cost of laying per ft.	$0.156

The cost of materials for this 4-in. pipe line was as follows:

	Per ft.
Pipe (2,820 ft., 30 short tons), at $44.40	$0.461
Specials (4,462 lbs.), at 3¼ cts.	0.051
Valves (9), at $9.40	0.030
Hydrants (5), at $28.60	0.050
Lead (2,010 lbs.), at 5.3 cts.	0.038
Yarn (105 lbs.), at 5.4 cts.	0.002
Tools	0.015
Miscellaneous	0.006
Total materials per ft.	$0.653

Cost of 6-in. water pipe line (838 ft. long, of which 300 ft. were in sand):

	Per ft.
Labor trenching, at 20 cts. per hr	$0.075
Two horses trenching, at 15 cts. per hr	0.001
Labor digging bell-holes, at 20 cts. per hr	0.017
Labor laying pipe, at 20 cts. per hr	0.013
Yarners, at 22½ cts. per hr.	0.005
Labor pouring, at 20 cts. per hr	0.007
Calkers, at 25 cts. per hr.	0.010
Labor backfilling, at 20 cts. per hr.	0.012
Two horses backfilling, at 15 cts. per hr	0.004
Miscellaneous	0.005
Distribution of materials, at 60 cts. ton	0.012
Foreman, at 40 cts. per hr.	0.018
Time keeper	0.002
Total cost of laying per ft.	$0.181

The cost of materials for this 6-in. pipe line was as follows:

	Per ft.
Pipe (816 ft., 13.12 tons), at $43.40 per ton	$0.679
Specials (1,420 lbs.), at 3¼ cts.	0.055
Valves (10), at $15.65	0.187
Hydrants (9), at $29.85	0.320
Lead (804 lbs.), at 5.3 cts.	0.052
Yarn (42 lbs.), at 5.4 cts.	0.003
Tools	0.016
General	0.010
Total materials per ft.	$1.322

Cost of 8-in. water pipe line (2,558 ft. long, of which 800 ft. were in sand):

	Per ft.
Labor trenching, at 20 cts. per hr	$0.071
Labor digging bell-holes, at 20 cts. per hr	0.016
Labor laying pipe, at 20 cts. per hr	0.016
Yarners, at 22½ cts. per hr.	0.006
Labor pouring, at 20 cts. per hr	0.006

	Per ft.
Calkers, at 25 cts. per hr.	0.013
Labor backfilling, at 20 cts. per hr.	0.012
Two horses backfilling, at 15 cts. per hr.	0.004
Miscellaneous	0.004
Distributing materials, at 60 cts. per hr.	0.016
Foreman, at 40 cts. per hr.	0.017
Time keeper	0.002
Total cost of laying per ft.	$0.183

The cost of materials for this 8-in. pipe line was as follows:

	Per ft.
Pipe (2,512 ft., 57.61 tons), at $43.40	$0.978
Specials (4,056 lbs.), at 3¼ cts.	0.052
Valves (5), at $24	0.047
Lead (3,618 lbs.), at 5.3 cts.	0.076
Yarn (189 lbs.), at 5.4 cts.	0.004
Tools	0.015
Miscellaneous	0.009
Total materials per ft.	$1.181

Cost of 10-in. water pipe line (124 ft. of pipe, 14 ft. of specials; total, 138 ft.):

	Per ft.
Labor trenching, at 20 cts. per hr.	$0.174
Labor digging bell-holes, at 20 cts. per hr.	0.015
Labor laying pipe, at 20 cts. per hr.	0.022
Labor yarning, at 20 cts. per hr.	0.002
Labor pouring, at 20 cts. per hr.	0.002
Labor calking, at 20 cts. per hr.	0.015
Labor backfilling, at 20 cts. per hr.	0.060
Labor miscellaneous, at 20 cts. per hr.	0.015
Distribution of materials, at 60 cts. ton	0.020
Foreman, at 40 cts. per hr.	0.016
Time keeper	0.002
Total labor per ft.	$0.343

The cost of materials for this 10-in. pipe line was as follows:

	Per ft.
Pipe (124 ft., 3.75 tons), at $43.40	$1.179
Specials (603 lbs.), at 3¾ cts.	0.178
Valves (1), at $34.60	0.251
Lead (268 lbs.), at 5.3 cts.	0.105
Yarn (14 lbs.), at 5.4 cts.	0.005
Tools	0.015
Miscellaneous	0.009
Total materials per ft.	$1.742

Cost of 78 service connections (¾-in. screw pipe):

	Each.
Labor trenching, at 20 cts. per hr	$0.613
Tapping and making, at 40 cts. per hr	1.003
Tapping and helper, at 20 cts. per hr	0.289
Backfilling, at 20 cts. per hr	0.206
Total labor per connection	$2.111

The cost of materials for each service connection was as follows:

	Each.
Goosenecks and cocks	$2.48
Fittings	0.40
Tools ($68)	0.88
Tapping machine ($81)	1.03
Total materials and tools per connection	$4.79

It will be noted that the full cost of the tools and tapping machine is charged to these 78 connections, making the cost of each unusually high.

Assuming, as above stated, that the trenches averaged 1½ ft. wide and 3⅓ ft. deep, the cost per cubic yard of trench work was as follows:

	Cents.
Digging trench	38
Digging bell-holes	8½
Backfilling	8½
Total per cu. yd	55

An Unusually Expensive Piece of Work.—"G. S. W. '88" in The Technic of 1896, gives the following, the material in all cases being clay: Wages of laborers 15 cts., pipe handlers 16 to 17½ cts., foreman 20 cts. per hour; depth of trench, 4 to 5½ ft.:

Example	A	B	C	D
Size of pipe, ins	24	24	12-16	10
Length of pipe, ft	2,550	2,200§	6,241	8,969
Excavation, cu. yds	2,710	1,963	3,441	4,508
Surplus earth,* cu. yds	1,300	862	1,033	......
Cost of excavation per foot	$0.2725	$0.333	$0.2061	$0.2416
" pipe laying, per ft	.2480	.182	.2089	.0939
" bell holes, per ft	.1500	.128	.0954	.0098
" backfilling, per ft	.1790	.191	.1228	.1360
" ramming, per ft	.7927†	.107‡	.2896†	.1322†
" tile, hose work, per ft	......	.074	......	.0200
" load'g excess earth, ft	.0895	.046	.0358	.0025
" cart'g excess earth, ft	.0636	.055	.0635	.0046
Total labor cost per ft	$1.7953	$1.116‡	$1.0318‖	$0.6433
Cost of excavation, cu. yd	0.2562	0.373	.3736	.4807
" backfilling, cu. yd	0.1684	0.216	.2226	.2706
" ramming, cu. yd	0.7461†	0.121‖	.5434†	.8618†
" tile, hose work, cu. yd	......	0.084	......	......
Swelling of material on loosening	44%	30. to 44½%*	20%	......

* This surplus earth was hauled away in wagons, after filling the trenches and leaving a 4-in crown to provide for settlement.

§ 1,400 feet of this trench was backfilled without ramming, using water instead; ramming, however, was much more effective in compacting the clay.

† Rammed dry in 4-in layers.

‡ Rammed wet; the portion that was rammed dry cost $1.40 per ft total.

‖ This total does not check with the items, so there must be an error somewhere.

With labor at $1.25 for 8 hours and material clay as before, streets paved with wood. "G. S. W." also gives the following:

Example	E	F	G	H
Size of pipe in ins	12	12	10	8
Depth of trench, ft	5	5	5	5
Length of trench, ft	1,048	2,475	2,592	2,049
Cost of excavation, per ft	$0.186	$0.134	$0.1920	$0.1442
" pipe laying, per ft	.257	.162	.1218	.0678
" backfilling, per ft	.450	.390	.3949	.3632
" hauling surplus, per ft	.014	.011	.0101	.0194
Total labor cost per ft	$0.907	$0.697	$0.7188	$0.5746

The two most striking features in the foregoing data are (1) the enormous swelling of the clay upon loosening and casting it out of the trenches, and (2) the extraordinary high cost of ramming the clay in backfilling. It is difficult to explain either of these items except upon the assumption that the loosened clay dried out when exposed to the sun and air, forming hard rock-like clods which no amount of ramming seems to have consodidated effectually. Adding water as in Example B seems to have had no very good effect in consolidating the backfill, although it was less expensive than ramming. But it is a well-known fact that water makes dry clay swell, and it does not cause layers of hard lumpy clay to settle in a trench except as a result of weeks of slow seepage of rains.

It will be noted that all this work was extraordinarily expensive. Even the pipe laying cost double the usual amount. We may infer that this work was not done by contract but by day labor for a municipality or a company, and that the foreman did not secure "a day's work" from the men—which is so often the case in municipal day-labor work.

Cost of a 6-in. Pipe Line in Ohio.—Mr. E. H. Cowan has given me the following data: A 6-in. pipe line, 1½ miles long, was laid in an Ohio city by contract, the cost per foot of pipe line to the contractor being as follows:

	Per ft.
33.74 lbs. of 6-in. pipe, at $24 per short ton......	$0.405
0.67 lb. of specials, at 2¾ cts. per lb............	0.018
Hydrant connections, 4-in.	0.008
Hydrants, $26 each	0.066
Gates ($12.60 each) and gate boxes ($3.09 each)..	0.054
0.74 lb. lead, 4½ cts. per lb......................	0.033
0.07 lb. jute packing, 3¾ cts. per lb............	0.003
Labor, 18½ to 26 cts. per ft., averaging..........	0.211
Teaming, 49½ cts. per short ton................	0.009
Miscellaneous items	0.008
Total	$0.815

The working force was as follows:

1 foreman, at $2.50 per 10-hr. day.
2 sub-foremen, at $2.00.
9 men in pipe gang (including 2 calkers), at $1.75.
32 laborers digging trench, at $1.50.
12 laborers backfilling, at $1.50.
1 waterboy, at $1.00.

At times the backfilling gang was engaged in trench digging. Trenches were 5 ft. 2 ins. deep. The digging ranged from the easiest spading to the hardest picking, the average being "average earth." Could the contractor have been present all the time, the cost might have been less. The backfilling was done by hand, and it was not rammed, but the trench was flushed with water. No material was hauled away. The work was done in August and September, 1903, and there was very little rain. It was not necessary to brace the trench except at a few spots.

Cost of Water Pipe Laid in a Southern City.—In Engineering News, March 30, 1893, Mr. C. D. Barstow gives very complete tables of cost of shallow trenching and pipe laying in a southern city, where negro laborers were used. From the data given by him I have compiled the following tables of cost:

For the most part the trenches were 18 ins. wide at bottom and 20 ins. at top, and 3 ft. deep. Some trenching was done using a team on a drag scraper, 20 ins. wide; then the trench was made 3 ft. wide at top. Using teams was more economical, as may be seen by comparing C with D in the foregoing table. After a rain, however, the scrapers could not be used to advantage. In using a plow for loosening the earth, several feet of chain are fastened to the end of the plow beam, and one or more men ride the beam; in this way plowing may be done in a trench 4 ft. deep, one horse walking on one side and one on the other side of the trench. A blacksmith was kept busy sharpening about 60 picks a day. There was a night watchman. The pipe was distributed by contract at 34 cts. per ton.

TABLE OF COST OF TRENCHING AND PIPELAYING IN THE SOUTH.

Wages per 10-hr. day for negro laborers, $1.25; for calkers, $1.75; for white foremen, $3.00; for teams, $3.25; for horse ridden by boy, $1.50.

Job	A	B	C	D	E	F
Pipe, ins	10[1]	......	6	8	10	8[8]
Length, ft	11,000	6,000	6,215	11,352	2,636	21,856
Width trench, ft	2	......	......	......	......	......
Depth trench, ft	3.5	3	3	3	3	3
Material	......[2]	......[4]	......	......	......	......[9]
No. laborers digging	33	30	40	31	45	46
No. teams plowing	......	......	......	3½	5	2½
Team time, cts. per ft	......	......	......	0.80	0.62	0.60
Labor, digging, cts. ft	6.66	2.74	5.19	2.68	2.12	4.00
Foreman, digging, cts., ft.	0.50	0.23	0.31	0.21	0.12	0.20
Labor, pipe laying, cts. ft.	2.04	......	0.68	0.77	0.94	1.12
Foreman, pipe lay'g cts. ft	0.39	......	0.17	0.21	0.18	0.24
Bell hole digging, cts., ft.	2.70	......	0.77	0.98	0.93	1.16
Bell hole digging, foreman, cts. per ft	0.27	......	0.16	0.21	0.18	0.18
Calking, cts., per ft	1.30	......	0.52	0.64	0.63	0.75
Backfill and tamp:						
Labor, cts., per ft	4.32[3]	1.00[5]	1.01[6]	2.09	1.42[7]	0.95[9]
Foreman, cts., per ft	0.36	0.22	0.22	0.32	0.18	0.18
Team,* cts. per ft	.....	.....	0.36	.....	.....	0.41
Horse rid'n by boy, cts. ft.	.....	.....	0.07	.....	0.09	.....
Total cost, cts. per ft	18.54	4.19	9.46	8.91	7.41	9.79

*Backfill with drag scraper.

[1]Trenching in an old street, 1,200 ft. in very muddy ground. Two rainy spells in 18 days of work. Then 10-in. pipe was laid for 3,440 ft.; then 4,038 ft. of 12-in. pipe were laid for 1¼ cts. per ft. less than it cost for the 10-in. pipe.; then 3,270 ft. of 8-in. pipe were laid for 2¼ cts. per ft. less than it cost for the 10-in.

[2]Cemented clay and gravel requiring hard picking. Frequent rains.

[3]The backfilling and tamping were done most thoroughly, a stretch of 2,550 ft. requiring 3 days for 30 men.

[4]Sand and loam, bottom land, very easy digging.

[5]Very easy shoveling and no tamping; 11 men 7 days backfilled 9,620 ft. of trench.

[6]Dragscrapers used to backfill; boy riding horses to tamp, gang 22 men, 3 teams, 1 boy and horse, 2 days on 5,447 ft.

[7]Backfilled 1,670 ft. in one day by 19 men, using 1 boy and horse on tamping.

[8]Half the pipe was 8-in. at cost here given, half was 6-in. costing ½-ct. less per ft. for laying.

[9]Ground wet and often muddy. Backfilling 11,433 ft. done by 12 men and 2 teams on scrapers in 7 days; no tamping.

The lead and yarn consumed per ft. of pipe (length 12 ft.) was:

1.3 lbs. of lead and .04 lb. of hemp for 12-in. pipe.
.96 lb. of lead and .04 lb. of hemp for 10-in. pipe.
.95 lb. of lead and .03 lb. of hemp for 8-in. pipe.
.66 lb. of lead and .02 lb. of hemp for 6-in. pipe.

Some 6,000 ft. of 2-in. wrought-iron service pipe was laid in trenches 2 ft. deep, at a cost of 1.9 cts. for trenching,

0.24 ct. for laying pipe, and 0.71 ct. for backfilling—there was no tamping done.

For a distance of 373 ft. a trench 2 ft. wide and 3 ft. deep passed through a street paved with brick laid on 7½ ins. of concrete. The brick was removed for a width of 3 ft. and the cost was as follows:

		Men, days	Cts. per lin. ft.
Removing brick and concrete	Foreman	0.5	
	Laborers	7.0	2.61
Excavating trench	Foreman	0.5	
	Laborers	18.0	6.30
Backfilling and tamping well	Foreman	1.0	
	Laborers	10.6	4.09
Labor relaying concrete		7.8	2.61
" " bricks		4.5	
Professional brick pavers		4.0	4.59
" " helpers		2.0	
Hauling away 23 loads surplus earth			1.23
15 cu. yds. sand cushion			4.02
1,700 new bricks			6.92
18¼ bbls. cement to relay concrete			6.20
Total			38.58

Cost of Taking Up an Old Pipe Line.—Mr. E. E. Fitzpatrick furnishes the following data relative to taking up more than 3 miles of pipe line at Greenburg, Kansas. There were 10,200 ft. of 4-in. pipe; 4,310 ft. of 6-in.; 2,050 ft. of 8-in., and 890 ft. of 10-in. After digging the trenches, the 8-in. and 10-in. pipes were raised a little, and fires built under the joints until the pipe expanded; then the pipes were unjointed by working them up and down with a three-leg derrick. The 4-in. and 6-in. pipes were raised bodily in long sections onto the bank, heated a little, and unjointed by means of jack-screws and clamps. The time required to do all the trenching, backfilling and unjointing, was equivalent to the work of 1 man for 425 days; and, assuming wages at $1.50 a day, the cost was only 3¾ cts. per foot of pipe.

Cost of Subaqueous Pipe Laying.—A line of 12-in. water pipe was laid in a trench dredged across a river 500 ft. wide, as follows: The water in the river averaged 4 ft. deep and the trench was dug 6 ft. deep, making a depth of 10 ft. from water surface to bottom of the trench. The small home-made dredge, described in my book on

Earthwork, was used for the dredging. To lower the pipe into the trench A-frame bents were built of 4 × 6-in. timber, the legs of the bents straddling the trench, and each pipe was supported by an iron rod passing through a hole bored in the horizontal member of the A-frame. These rods were about 12 ft. long, ⅝-in. diameter, and threaded their full length. Each rod was provided with a hock at its lower cnd to hook into an iron ring around the pipe. The pipe was ordinary cast iron pipe, and was leaded and calked while suspended from the A-frames. Then it was the intention to lower the 500 ft. of pipe all at one time by putting a man with a monkey-wrench at each rod, to give the nut on the rod a turn at a given signal from a whistle. There were 43 bents, 12 ft. apart, and it was decided that a force of 10 men could lower the pipe satisfactorily by giving a few turns of the nuts on 10 rods, then moving to the next 10 rods, and so on. Through carelessness or mischief, some of the men gave more turns to the nuts than the signals called for. This threw the weight of several pipes upon two or more rods, and broke one of them at the hook, which was the weak spot. Immediately all the other rods broke in rapid succession, dropping the pipe line into the river. The pipe settled to the bottom without breaking in two anywhere, and only one joint showed any leakage of air when I inspected the line immediately after the accident. This joint was calked by a man who dived down repeatedly, and struck a few blows each time he was down. However, a diver was sent for to examine every joint, and his inspection showed the pipe line to be intact from end to end. The cost of building the A-frames, placing and calking the pipe line was as follows:

10 men, 3 days, at $1.75	$52.50
1 foreman, 3 days, at $3.00	9.00
10 men, 1 day at work lowering pipe, at $1.75	17.50
1 foreman, 1 day at work lowering pipe, at $3.00	3.00
1 diver, 1 day inspecting line	25.00
Traveling expenses of diver	15.00
Total for 516 ft. of pipe	$122.00

The above does not include the cost of the iron rods, nor the timber used in the bents, nor the building of a small raft from which to erect the A-frame bents.

From this experience I believe it would be safe to dispense with the threaded iron rods for lowering such a line of pipe. The pipe could be held just above the water surface by small manila ropes, until calked. Then upon cutting one or two of the ropes, the rest would break and allow the pipe to settle into the water. As the pipe line is quite bouyant, when filled with air, it settles down gently upon the bottom of the trench. In case a break should occur in the line, threaded rods could be made, and the pipe raised and repairs made at but slightly greater expense than would have been incurred had rods been used in the first place. When pipe is lowered as above described, one flexible pipe joint is usually provided at each end of the pipe line.

Cost of Laying Pipe Across the Susquehanna.—Mr. James P. Herdic gives the following data relating to laying 10-in. cast iron pipe across the Susquehanna River, at Montoursville, Pa., a distance of 600 ft., average depth of water being 13 ft. A ⅞-in. manila rope was first stretched across the river, to act as a ferry line for the scows. The scows were loaded with pipe. The crew of 8 men and foreman were engaged 1 day in this preliminary work, and then laid the 600 ft. of pipe line in the next 2½ days. One ball and socket joint was used to every six ordinary joints. The pipe line was lowered between the two scows, by means of chain pulleys suspended from a heavy sawhorse that spanned the gap between the two boats. The pipe was laid in a gentle curve, bowed up stream, so as to form an arch to resist the stronger currents. This is certainly an excellent record for economic work.

On another place in the Susquehanna River, where the current was so swift that it would swamp a scow if held sidewise in the current by a cable, as above described, the following method was used: A scow was held in the current with its nose up stream, but at an angle with the current; ropes from bow and stern to the nearest shore serv-

ing to hold it. In this way the current kept the ropes taut, and the scow remained steady while the lead joints were poured. The pipe line lay across the middle of the scow, which was moved out from under each joint as fast as made. Six common joints to each ball and socket joint were used.

Cost of Laying a 6-in. Pipe Under Water.—About 5,100 ft. of 6-in. pipe were laid from the New Jersey shore to Ellis Island under 10 to 17 ft. of water. A trench was dug 5 ft. deep by 10 ft. wide in the mud, using a clam-shell bucket. Heavy pipe, weighing 800 lbs. per length, provided with Ward flexible joints, was used. Two scows, each 26 × 80 ft., were fastened together, 6 ft. apart, and provided with two skids of 10 × 10-in. timbers 55 ft. long, leading down between the scows to the bottom of the trench. The skids could be lowered in rough weather. Two lengths of pipe were placed at one time on the skids, a derrick being used for the purpose, and then the scows were warped ahead 24 ft. The whole work occupied just a month, using a force of 10 laborers, 2 calkers and 1 diver to calk any leaks, etc. The best day's work was 516 ft. The line was tested under 80 lbs. pressure, and leaked only 5 cu. ft. in ½-hr.

Cost of Laying Pipe Across the Willamette River.—In Eng. Record, Sept. 19 and 26, 1897, the laying of 32-in. pipe across the Willamette River, Oregon, is described. Two scows and an inclined cradle were used. The gang was 16 men and 1 diver, and they laid 80 ft. of pipe per day in a trench 23 ft. below the water surface.

Cost of a Wood-Pipe Line.—Mr. James D. Schuyler, in Trans. Am. Soc. C. E., Vol. 31 (1894), describes and illustrates very fully the building of a wooden pipe line for Denver, Col. The pipe was 30 ins. diameter, made of staves of Texas pine 1¼-in. thick, with ½-in. round iron bands. A pipe laying gang consisted of 8 to 16 men according to the number of bands per unit of length, half the gang being employed in back cinching. On a 34-in. pipe a gang placed 700 to 1,000 bands per day, laying from 150 to 300 lin. ft. of pipe. On a 44-in. pipe the rate was

500 bands per day. The cost of erection was from 5 cts. per band on a 30-in. pipe to 10 cts. per band on a 48-in. pipe. The cost of 16.4 miles of 30-in. pipe was $1.36 per ft., distributed as follows:

1,869 M Texas pine, at $27.50	$51,399
271,900 steel bands (½-in.) and shoes	54,300
Erection of pipe, 5.1 cts per band, by contract	13,866
	$119,565

In addition the trenching and backfilling cost 48 cts. per ft., which was unusually expensive.

Cost of a 64-HP. Gasoline Pumping Plant and Pumping.—Mr. P. E. Harroun gives the following on the cost of a gasoline pumping plant for the water-works of Porterville, Cal., having a population of 2,000:

Two gasoline engines:

Two gasoline engines, each 32 HP	$2,860
Hauling and placing on foundations	90
Two belt tighteners	76
Framing and placing same	22
Fittings, foundation bolts, tubes, etc	48
Labor, lining up, adjusting, etc., 30 cts. per hr	38
Belting	141
Miscellaneous	11
Cost of two engines in place	$3,286

Two pumps:

Two 9 × 12-in. single acting triplex pumps	$2,816
Hauling and placing on foundations	170
Foundation bolts, tubes and setting same	42
Special castings	372
Pipe, flanges and bolts	248
Valves	160
Fittings, gaskets, miscellaneous and blacksmithing	134
Labor connecting up	100
Ejector, pipe fittings and connecting up	38
Cost of two pumps	$4,080

This makes the combined cost of engines and pumps, exclusive of concrete foundations, $7,366.

The cost of pumping with this plant into a stand-pipe was as follows, in the month of May, 1904:

1,700 gals. crude Coalinga oil, at 4 cts..........	$68.00
22 gals. engine oil, at 50 cts..................	11.00
5 gals. engine gasoline, at 30 cts............	1.50
25 gals. pump oil, at 50 cts.	12.50
8 lbs. pump gear compounds, at 25 cts......	2.00
20 lbs. waste, at 10 cts.	2.00
½ time of superintendent	50.00
Full time of assistant superintendent......	65.00
Total per month	$212.00

During this month the pumps raised 12,678,000 gals. a height of 164 ft.; the pumps actually pumped 458 hrs. This makes the cost a trifle more than 10 cts. per million gallons raised 1 ft. high. There were 1,200 consumers who used 340 gals. per capita. The crude oil weighs 7¼ lbs. per gal., and develops 19,600 B. T. U. per gal. The best performance of the plant, extending over several days, has been 1.43 pints of crude oil per horse-power hour. The combined efficiency of the pump and belting was 70%, so that 1 pint of crude oil developed about 1 B. HP. per hr. Half of the superintendent's time is charged to the plant and half to the office expense of the water-works system.

Cost of a Pump-Pit.—Mr. P. E. Harroun gives the following data on excavating a circular pump-pit 26 ft. deep and 22 ft. in diameter. The work was done in Porterville, Cal., in 1904, by company labor which was not efficient, and was high priced. In sinking the pit, the upper 8 ft. were river silt, then came 5 ft. of coarse gravel carrying a large volume of water, and the remaining 13 ft. were in clay. The clay was very hard to pick, and contained many seams carrying water. The sides of the pit were covered with spouting streams and the bottom of the pit was a series of small geysers. On account of the sloughing of the sides, it was necessary to timber the pit from

top to bottom. The timbering consisted of 4 × 12-in. rangers or wales, and braces, sheeted with 2-in. plank driven vertically, as in sewer work. The earth was loaded with shovels into dump boxes, holding ⅓-cu. yd. each, and raised with a derrick, the hoisting power being a pair of mules. One box was loaded while the other was being dumped into a wagon. The following costs do not include the hauling away in wagons or the cost of pumping the pit:

	Per cu. yd.
Laborers, at 20 cts. per hr.	$0.58
Team of mules, at 20 cts. per hr.	0.06
Foreman of laborers (130 hrs.), at 30 cts. per hr.	0.08
Tools and blacksmithing	0.14
Lumber (7¼ M, at $22)	0.36
Miscellaneous material	0.04
Carpenter (160 hrs.), at 35 cts.	0.11
Carpenter's helper (154 hrs.), at 20 cts.	0.07
Foreman of timbering (130 hrs.), at 30 cts.	0.08
Total per cu. yd., for 454 cu. yds.	$1.52

It will be noted that the carpenter work, including helper, cost $11.50 per M of timber. There were 10 laborers, 1 team of mules, and 1 foreman, at work about 13 days (10-hr.), doing the excavating.

A circular reservoir 4 ft. deep and 52 ft. in diameter was excavated in stiff adobe (clay), and about 300 cu. yds. were loaded with pick and shovel into wagons and hauled away. The cost of this pick and shovel work alone was 59 cts. per cu. yd., wages being 20 cts. per hour.

SECTION VIII.

COST OF SEWERS, VITRIFIED CONDUITS AND TILE DRAINS.

General Considerations.—Trenches for sewers are usually much deeper than trenches for water pipes, because it is generally considered desirable to have a sewer deep enough to drain cellars and basements. In cities a common depth is 8 to 11 ft. If the depth is more than about 6 ft., even in narrow trench work, men will be required on the surface to shovel the earth back from the edge of the trench after it has been cast up. In such cases always cast the earth onto plank, for reasons given in Section 2 on Earthwork. When the depth much exceeds 8 ft., it is advisable to cast the earth out of the trench in stages, using platforms about 6 ft. apart—or less if the earth is sloppy. Bear in mind that where the trench is a wide one, there is much handling of the earth after it reaches the surface, both in stacking it up in piles and in moving it back into the trench ("backfilling") after the sewer has been laid. In large sewer construction there is more excavation than backfill, and the excess must be loaded and carted away. Each case must be estimated separately, which can be done with the data given in Section 2 on Earthwork, and with the data in this section and in the previous section on Water-works.

Deep trenching is beset with so many difficulties, such as the handling of unexpected bodies of water, the caving of banks even when well sheeted, and the like, that liberal estimates of cost should always be made. Then $7 to $10 a day should ordinarily be added for rental of a trench machine, for even where owned by the contractor a liberal allowance must be made for wear and tear and

interest, since so much of the time the machine is ordinarily idle. The cost of the sheeting plank must be added, also that of pumping. In many localities glacial boulders are likely to be encountered, greatly delaying work and adding to the cost.

Accidents to men are frequent—so much so in some soils that accident insurance companies absolutely refuse to insure a sewer contractor's men. Accident insurance is seldom less than 1% of the pay roll, even on safe work, and on sewer work it often runs up to several per cent.

Cost of Excavating With Trench Machines.—A trench machine, as the term is here used, does not mean an earth digger, but an earth conveyor. The Carson trench machine is a good example of the type. It consists essentially of a single rail track on which a trolley travels, being hauled back and forth by the cables of a hoisting engine. The trolley carries the bucket into which the earth or rock has been loaded by hand. The single rail track is supported at intervals by a light trestle made of bents that are A-shaped.

The legs of the A-bents are provided with wheels at the bottom riding on a track straddling the trench, and the whole trestle can be moved forward in 5 to 10 mins., from time to time, as the work advances, without taking the trestle apart, unless a curve has to be rounded. These A-bents are of 6 × 8-in. spruce, 20 ft. high and have a spread of 18 ft. at the bottom. The trestle is 288 ft. long, and buckets of 1 cu. yd., each are handled. The crew and the cost of operation are the same as for a cableway.

Mr. A. W. Byrne states that in completing one 4,000-ft. section of the Metropolitan sewer system, at Boston, he used the following force:

1 engineman	$3.00
1 lockman	2.00
1 dumper	1.50
8 shovelers, at $1.75	14.00
2 bracers, at $2.50	5.00
2 tenders, at $2.00	4.00

4 plank drivers, at $2.00	$8.00
2 men cutting down planks, at $2.00	4.00
8 men pulling planks, etc., at $1.75	14.00
Total	$55.50

This force working in a trench 9 ft. wide × 20 to 30 ft. deep averaged 64 lin. ft. a week in "boiling sand," the pressure of which would break 6 × 8-in. stringers 2½ ft. apart, and 192 ft. a week in gravel and coarse sand, which is equivalent to 70 to 110 cu. yds. a day in the running sand, and 200 cu. yds. in good ground, or at a cost ranging from 80 to 25 cts. cu. yd. A steam pump running at a cost of $10 a day was also required, and about ½-ton of coal was used by the trench machine. The work mentioned was done after the trench machine was set up, and the gang well organized. Another contractor states that it took him two days to dismantle a machine, move it 1,000 ft. and set up again.

The Adams trench machine consists of a series of wrought-iron, ∩-shaped bents, the lower feet of the ∩ being provided with wheels running on rails laid each side of the trench. These ∩ bents carried two rails, on each side, beneath the top of the bent, and a car ran along these rails; this car is pulled back and forth by cables from a hoisting engine at one end of the trench; and the same engine raises buckets up to the car where they are gripped. Working in sand at Peoria, Ill., the following was the cost in a trench 13 ft. wide × 45 ft. deep:

	Per day.
18 men loading buckets, at $1.50	$27.00
1 man operating bucket car	2.00
1 foreman	3.00
1 engineman	2.50
1 waterboy	.50
Coal, oil, etc.	1.00
Total per day	$36.00

This force excavated 284 buckets of 1 1-9 cu. yds. each,

or 316 cu. yds., daily at a cost of 11.4 cts. per cu. yd., as the average of 1 month.

The same gang operating in a trench, 12 ft. wide × 33 ft. deep, averaged 288 buckets a day, at a cost of 12.5 cts. per cu. yd. Most of the excavated material was dumped directly from the buckets as backfill into the trench where the sewer was completed.

A Moore Hoister and Conveyor, which differed only in having the bucket car travel on top of the bent, instead of below, required one more man handling the buckets, making the daily force account $38. In a trench 12 ft. wide × 35 ft. deep the Moore machine daily averaged 286 buckets of 1 cu. yd. each, at a cost of 13.3 cts. per cu. yd.

These records for Adams and Moore machines show unusually low costs. They should not be taken as averages, but rather as showing the very best that can be done under favorable conditions. Mr. A. D. Thompson is my authority for these cost records. The cost of sheeting these trenches is given on pages 435 and 436.

Cost of Difficult Trench Excavation in Mass.—Mr. H. H. Carter gives the following account of work done by contract in Massachusetts in 1884: A trench 2,100 ft. long, 9½ ft. deep and 20 ft. wide was dug for a conduit along the shore of a pond and about 30 ft. away from the water's edge. The water in the pond was 8 ft. higher than the bottom of the trench, but most of the water that entered the trench seeped in from the side farthest away from the pond. The water was handled by two Pulsometer Steam Pumps. A large quantity flowed in at some places. All water was pumped from sumps located ahead of the laying of the brick conduit. No underdrains were left under the finished conduit. The material excavated was variable. The greater part of the conduit was built on a hard, coarse sand and gravel bottom; but for several hundred feet quicksand was encountered in the bottom. A Carson trench machine was used for 10 weeks. The total excavation was 15,100 cu. yds., or 7.2 cu. yds. per lin. ft. of trench. The backfill amounted to only 1.5 cu. yds. per lin. ft. of trench. The itemized cost was as follows for 2,100 ft., or 15,100 cu. yds.:

	Total.	Per cu. yd.
Foreman, 66 days at \$4.00	\$264.00	\$0.044
" 159 days at \$2.50	397.50	
Engineman, 123 days at \$2.50	307.50	0.020
Fireman, 147 days at \$1.75	257.25	0.016
Pumpman, 94 days at \$3.00	282.00	0.026
" 56 days at \$1.75	98.00	
Laborer, 2,400 days at \$1.25	3,000.00	0.200
" 2,200 days at \$1.50	3,300.00	0.220
Bracer, 366 days at \$1.75	640.50	0.042
Carpenter, 7 days at \$2.00	14.00	0.001
Horse and cart, 88 days at \$4.00	352.00	0.023
Horse and car, 10 days at \$3.15	31.50	0.002
Scraper, 71 days at \$5.00	355.00	0.024
Carson machine, 10 weeks at \$45.00	450.00	0.030
Engines, 103 days at \$2.00	206.00	0.014
Boiler, 129 days at \$1.00	129.00	0.009
Pumps (two), 199 days at \$0.80	159.20	0.011
Derricks, 72 days at \$1.00	72.00	0.005
Tools	71.00	0.005
Coal, 80 tons at \$6.00	480.00	0.032
Sheeting, loss on, at \$14 per M	200.00	0.013
Iron, at 3 cts. per lb.	15.00	0.001
Miscellaneous	26.00	0.002
Total	\$11,107.45	\$0.740

The backfilling and embankment cost is included in the above cost of 74 cts. per cu. yd. of trench excavation. Properly it should be separated, as follows:

	Per lin. ft.
Excavating trench	\$3.20
Bracing trench, labor	0.30
" " lumber	0.10
Pumping trench	0.45
Backfilling	0.71
Embankment	0.69
Miscellaneous	0.28
Total per lin. ft.	\$5.73

Deducting the backfilling and embankment, we have left \$4.33 per lin. ft., or 60 cts. per cu. yd. of trench. The backfilling itself cost 18 cts. per cu. yd. backfilled.

This same trench work was extended across a pond that had been filled with an embankment of gravel and sand from a trestle. The trench was excavated in the center of this embankment, and was 18 ft. wide, with sheet piles on both sides, and its bottom was 6 ft. below the level of the pond. The water was handled by two pulsometers and one Andrews pump. The trench was 1,550 ft. long, containing 8,070 cu. yds. and took 125 days to excavate. The itemized cost was as follows:

	Total.	Per cu. yd.
Foreman, 35 days at $3.50	$122.50	$0.015
" 150 days at $2.50	375.00	0.047
Engineman, 146 days at $2.50	465.00	0.058
Pumpman, 286 days at $1.75	500.50	0.062
Laborer, 400 days at $1.65	680.00	0.085
" 460 days at $1.50	690.00	0.086
" 2,500 days at $1.25	3,125.00	0.383
Bracer, 255 days at $1.75	446.25	0.056
Horse and car, 12 days at $3.15	37.80	0.004
Engines, 125 days at $2.00	250.00	0.031
Boiler, 125 days at $1.00	125.00	0.015
Pulsometers, 223 days at $0.80	178.40	0.022
Pump (Andrews), 67 days at $2.00	134.00	0.017
Derricks, 125 days at $1.00	125.00	0.015
Tools	57.00	0.007
Coal, 52 tons at $6.00	312.00	0.039
Spruce, 49 M left in at $14.00	686.00	0.086
Miscellaneous	35.00	0.004
Total (1,550 lin. ft.)	$8,344.45	$1.032

This cost of $1.03 per cu. yd. includes some but not all of the backfilling. The cost per lin. ft. was distributed as follows:

	Per lin. ft.
Excavating	$3.25
Bracing, labor	0.29
" lumber	0.45
Pumping	0.72
Backfilling and embankment	0.66
Total	$5.37

Deducting the backfilling we have $4.71 per lin. ft., which is equivalent to 90 cts. per cu. yd. of trench. The backfilling itelf cost 19 cts. per cu. yd. backfilled. The contractor's price was less than half what the work cost him, but it appears evident that he did not manage his work very well.

Cost of Trenching by Cableways.—A cableway consists essentially of a main cable suspended between two towers, and serving as a track for the trolley carrying the loaded bucket, which is pulled back and forth by small cables from a stationary hoisting engine. The following data will give a good idea of what can be done with a cableway.

Parallel with a railroad track a trench 14 ft. wide by 18 ft. deep was dug in earth slightly more compact than "average." A Lambert cableway with towers 400 ft. apart was used, and it delivered the buckets to a chute that discharged into railroad cars alongside. The writer's record of cost was as follows:

	Per day.
30 men loading buckets, at $1.50	$45.00
1 signalman (signaling engineman), at $1.75	1.75
1 man hooking buckets to cable's trolley, at $1.75	1.75
1 man dumping buckets, at $1.75	1.75
4 men driving sheet plank and bracing, at $1.50	6.00
5 men spreading earth in cars and moving cars, at $1.50	7.50
1 engineman	3.00
1 fireman	1.75
1 waterboy	1.00
1 foreman	4.00
Total	$73.50

The output was 260 buckets in 10 hrs., each bucket holding 1⅓ cu. yds. of loose earth, which was probably not much more than 1 cu. yd. measured in cut. The wages and coal amounted to $76 a day. Hence, not including the cost of timber sheeting, nor the hauling and unloading of cars, the cost of excavation was about 30 cts. per cu. yd. There was no backfilling, as the trench was for a retaining wall. When the bucket was traveling 360 ft. from pit to dump, the following time was required for each round trip:

Raising bucket	15	seconds.
Moving bucket 360 ft.	35	"
Dumping bucket	25	"
Returning bucket	35	"
Lowering bucket	15	"
Changing buckets	15	"
Total	140	seconds.

Almost 5 secs. could be saved on each of these six items if everything went well, but with the ordinary slight delays the above is a fair average for each round trip—that is $2\frac{1}{3}$ mins. A cableway may be used to advantage in pulling sheet planking, and one 2 × 10-in. plank buried 16 ft. in the earth can be pulled in 1 min., thus making the cost of timber removal merely nominal. In pulling the plank use a piece of 1 × 3-in. iron bent into a U-shape and with a ring welded to one leg of the U. It clings to the plank even though it is not held by a set screw or the like.

To move one of these cableways takes a gang of 15 men three days if they are "green" at the work, two days if they are used to it. The anchorage for the main cable is made by digging a trench 5 or 6 ft. deep and 16 ft. long, in which a log 16 or 18 ins. in diameter and 15 ft. long is laid, and the cable carried around its centre. A short narrow trench leads off from the main trench so as to give a clear way for the cable to pass to the top of the tower. The main trench is filled with stones carefully laid over the log, and on top of the ground over the log is built a pile of stones 6 ft. high × 12 × 12 ft. To move all this rock for the anchors, to move the engine, towers, cables, etc., and set up again will seldom cost less than $50, and frequently costs $75, to say nothing of the lost time. If this cost is added to the cost of excavating the earth in a trench 370 ft. long, it will amount to several cents per cu. yd. Thus if the trench is only 6 ft. wide × 9 ft. deep, there will be 740 cu. yds. in 370 ft. of trench, and if it costs $74 to move the cableway, we have 10 cents per cu. yd. of trenching chargeable to the cableway moving, besides the cost of excavation and backfill. For deeper and wider trenches this cost of moving, being distributed over a greater yardage, becomes a com-

paratively small item. Each case must be treated as a separate problem, in ascertaining the cost.

The following data have been obtained from The Carson Trench Machine Co., of Charlestown, Boston, Mass., makers of the Carson-Lidgerwood cableway much used on the Rapid Transit Subway, New York City:

Two A-shaped bents or towers, 20 to 35 ft. high, and 200 to 300 ft. apart, support the 1½-in. cable along which the bucket travels. A hoisting engine at one end with two 7 × 10-in. cylinders and capable of lifting 5,000 lbs., raises and transports the buckets at a speed of 440 ft. a minute, or 5 miles an hour.

Aside from the men required to fill the buckets, the force required consists of an engineman, a fireman, a signalman, and a dumpman; and ⅓ to ½-ton of coal is daily consumed. On a sewer in Orange, N. J., 44 buckets (1 cu. yd.) were handled per hour on an average, 60 being the maximum. The output depends upon the number of men digging, and the character of the material, but 250 cu. yds. a day may be taken as a good output.

The following costs are given in letters to the Carson Trench Machine Co.:

Mr. Frank P. Davis, C. E., gives the following for a sewer in Washington, D. C.: Width of trench 18 ft.; depth at which cableway began work, 15 ft.; distance of travel of 1 cu. yd. bucket, 150 ft.; number of trips per hour, 35; hours per day, 8; material, cemented gravel. Cost:

Engineman	$2.00
Fireman	1.25
Signalman	1.00
2 dumpers, at $1	2.00
Coal, oil and waste	1.50
Interest and maintenance (estimated)	7.00
	$14.75
30 men picking and shoveling	30.00
Total for 280 cu. yds.	$44.75

Cost of picking, shoveling, hoisting 15 ft. and conveying 150 ft. to wagons, 16 cts. cu. yd. (Note that the wages were

very low.) Bracing and sheeting was going on at the same time; the men did not know they were being timed.

James Pilkington, of New York, says: "I have excavated and refilled 250 cu. yds. in 10 hours at an expense of 15 cts. per yard. For rock excavation the cableway has no equal. I have taken the machine down and moved 250 ft., and put up, and was in working order in three hours and fifty minutes." This is unusually fast and indicates that Mr. Pilkington did not raise his towers by "main force and awkwardness."

Cost of Trenching With Trench Excavators.—In Engineering News, Dec. 24, 1903, Mr. Ernest McCullough, Engineer for the Municipal Engineering and Contracting Co., Chicago, Ill., gives the following data relating to work done by the "Chicago Trench Excavator"—a machine made by that company.

The machine consists of an endless chain provided with cutters and scrapers which deliver the earth onto a traveling belt, the excavators and conveyors being carried by a four-wheeled traction engine, which furnishes the power. These machines are rented or sold to contractors.

In laying 7½ miles of pipe sewers at Mashfield, Wis., the daily cost of operating the machine and laying pipe was as follows:

Operator of trench digger	$3.00
Engineman of trench digger	2.75
Fireman of trench digger	2.25
Man trimming bottom of trench	2.25
2 men bracing trench with plank	4.00
2 pipe layers, at $2.50	5.00
2 men furnishing pipe and mortar	4.00
2 men tamping earth around pipe	4.00
1 man shoveling earth down to the tampers	2.00
2 teams and drivers scraping backfill	7.50
4 men holding the scrapers	8.00
Total labor per 10-hr. day	$44.75

About ¾-ton of coal was used daily.

The trench was 27 ins. wide and averaged 7 ft. deep. The best day's run was 850 lin. ft. of trench, or 500 cu. yds.

in 10 hrs., in dry clay containing no stones. On another day nearly 500 ft. were run in spite of many stops to blast out boulders. A fair average was 400 to 500 lin. ft., or 300 cu. yds., per day. Due to the jarring of the ground by the machine it is necessary to brace the trench.

(I am informed by Mr. McCullough that records of 650 cu. yds. per day have recently been made with this machine.)

These trench excavators are made in four sizes to excavate from 14 ins. to 60 ins. in width and up to 20 ft. in depth.

As confirming these data of Mr. McCullough's, the following records given by Mr. B. Ewing are of value: In the summer of 1904, many miles of pipe sewers were built at Wheaton, Ill., by contract. Two Chicago Excavators were used, cutting a trench 2½ ft. wide, 7 to 18 ft. deep. One machine would excavate 750 lin. ft. of trench 7 ft. deep through hard clay mixed with small stones, in a 10-hr. day. In cutting trenches 15 to 18 ft., a machine would average 150 to 200 lin. ft. per day, depending upon how much bracing was necessary.

Cost of Pumping Water From Trenches.—The cost of pumping water from trenches is given by Mr. Eliot C. Clarke as follows for three kinds of wet trenches, namely, "slightly wet," "quite wet" and "very wet."

In a "slightly wet" trench one hand-pump was used.

In a "quite wet" trench one steam-pump and a line of 8-in. pipe was used, sumps or wells being 500 ft. apart; the rent of this plant is rated at $3 a day; the engineman, $2.50 a day; the price of fuel is not given.

In a "very wet" trench two steam pumps and wells every 250 ft. were used; three enginemen.

The cost of pumping per lineal foot of trench was as follows:

Depth of trench, ft.	5	10	15	20	25
Slightly wet, cost per ft.	$0.06	$0.07	$0.10	$0.12	$0.18
Quite wet, cost per ft.	0.71	0.78	0.76	1.04	1.27
Very wet, cost per ft.	1.17	1.19	1.26	1.64	2.26

Sizes and Prices of Sewer Pipe.—The manufacturers of vitrified sewer pipe have adopted (Dec. 19, 1901) the

standard weights and list prices given in Table XVIII. Large discounts from these list prices are given. The present (July, 1905) discount, for New York City delivery, is 71% for all sizes up to and including 24-in. pipe; 59% for 27-in. and 30-in. pipe; and 50% for 33-in. and 36-in. pipe. The standard length is 2 ft. for pipes up to and including 24-in. pipe. The standard length is 2½ ft. for 27-in. to 36-in. pipe. The size of the pipe is designated by its inside diameter.

TABLE XVIII.

Prices and Weights of Standard Sewer Pipe.

Size, inches.	2 & 3	4	5	6	8	9
Straight pipe, per foot....	$0.16	$0.20	$0.25	$0.30	$0.50	$0.60
Elbows and curves, each.	0.50	0.65	0.85	1.10	2.00	2.40
Ys or Ts, inlets smaller than 15 ins., each......	0.72	0.90	1.13	1.35	2.25	2.70
Traps, each................	1.50	2.00	2.50	3.50	6.60	7.50
Weight, per ft., lbs........	7	9	12	15	23	28
Size, inches.	**10**	**12**	**15**	**18**	**20**	**21**
Straight pipe, per foot....	$0.75	$1.00	$1.35	$1.70	$2.25	$2.50
Elbows and curves, each.	3.00	4.00	5.40	6.80	9.00	10.00
Ys or Ts, inlets smaller than 15 ins., each......	3.40	4.50	6.10	7.65	10.13	11.25
Traps, each................	9.00	15.00	22.00	....	...	....
Weight, per ft., lbs........	35	43	60	85	100	120
Size, inches	**22**	**24**	**27**	**30**	**33**	**36**
Straight pipe, per foot....	$2.75	$3.25	$4.25	$5.50	$6.25	$7.00
Elbows and curves, each.	11.00	13.00	20.00	27.50	30.00	32.50
Ys or Ts, inlets smaller than 15 ins., each......	12.38	14.63	21.25	27.50	31.25	35.00
Weight, per ft., lbs.......	130	140	224	252	310	350

TABLE XIX.

Dimensions of Sewer Pipe.

Standard Pipe.

Size of Pipe.	Thickness.	Depth of Socket.	Cement Space.	Weight per ft.
2 in.	7/16 in.	1½ in.	¼ in.	6 lbs.
3 "	½ "	1½ "	¼ "	7 "
4 "	½ "	1⅝ "	⅜ "	9 "
5 "	⅝ "	1¾ "	⅜ "	12 "
6 "	⅝ "	1⅞ "	⅜ "	15 "
8 "	¾ "	2 "	⅜ "	23 "
9 "	13/16 "	2 "	⅜ "	28 "
10 "	⅞ "	2⅛ "	⅜ "	33 "
12 "	1 "	2¼ "	½ "	45 "
15 "	1⅛ "	2½ "	½ "	65 "
18 "	1¼ "	2¾ "	½ "	75 "
20 "	1⅜ "	3 "	½ "	95 "
21 "	1½ "	3 "	½ "	110 "
22 "	1⅝ "	3 "	½ "	125 "
24 "	1¾ "	3¼ "	½ "	145 "

Special Deep Socket Pipe.

Size of Pipe.	Thick-ness.	Depth of Socket.	Cement Space.	Weight per ft.
4 in.	½ in.	2 in.	½ in.	10 lbs.
5 "	⅝ "	2½ "	⅝ "	13 "
6 "	¾ "	2½ "	⅝ "	17 "
8 "	¾ "	2¾ "	⅝ "	25 "
10 "	⅞ "	2¾ "	⅝ "	35 "
12 "	1 "	3 "	⅝ "	48 "
15 "	1⅛ "	3 "	⅝ "	70 "
18 "	1¼ "	3¼ "	⅝ "	80 "
20 "	1⅜ "	3½ "	⅝ "	100 "
24 "	1¾ "	4 "	⅝ "	150 "

TABLE XX.

Dimensions of Double Strength Sewer Pipe.

Standard Socket.

Size of Pipe.	Thick-ness.	Depth of Socket.	Cement Space.	Weight per ft.
15 in.	1¼ in.	2¼ in.	½ in.	80 lbs.
18 "	1½ "	2½ "	½ "	100 "
20 "	1⅔ "	2¾ "	½ "	125 "
21 "	1¾ "	3 "	½ "	138 "
22 "	1⅝ "	3 "	½ "	155 "
24 "	2 "	3¼ "	½ "	200 "
27 "	2¼ "	4 "	¾ "	260 "
30 "	2½ "	4 "	¾ "	300 "
33 "	2⅝ "	5 "	1¼ "	340 "
36 "	2¾ "	5 "	1¼ "	380 "

Cement Required for Sewer Pipe Joints.—There are two kinds of sewer pipe: (1) The standard pipe with shallow joints; and (2) the special deep-socket pipe with wide and deep joints. The dimensions of these two kinds of joints are given in Tables XIX. and XX. Unless otherwise specified, the standard pipe with shallow joints is used; but many engineers prefer the deep-socket pipe, and specify it.

If the mortar is filled in the pipe joint and cut off vertically, flush with the face of the bell, the joint is called a "flush joint." If the mortar is also plastered on the outside, and beveled on a 1 to 1 slope from the outer edge of the bell to the body of the entering pipe, the joint is called an "overfilled joint" or a "beveled joint." The amount of mortar required for each of these kinds of joints is given in Tables XXI. and XXII. I have made no allowance for the space in the joint occupied by gasket or yarn. For discussion of the amount of cement per cubic yard of mortar see page 253.

TABLE XXI.

Cement Required to Lay 100 ft. of Standard Sewer Pipe
(2-ft. Lengths).

Size of pipe, ins..	4	6	8	10	12	15	18	20	24
Cu. yds. Mortar :*									
Flush Joints..	.009	.013	.014	.018	.025	.040	.050	.055	.065
Overfilled " ..	.020	.036	.058	.072	.087	.116	.160	.260	.310
Bbls. Cement (1 to 1 mortar):									
Flush Joints..	.036	.052	.056	.072	.100	.160	.200	.220	.260
Overfilled " ..	.080	.144	.232	.288	.348	.464	.640	1.04	1.24
Bbls. Cement (1 to 2 mortar):									
Flush Joints..	.027	.039	.042	.054	.075	.120	.150	.165	.195
Overfilled " ..	.060	.108	.174	.216	.261	.348	.480	.780	.930

TABLE XXII.

Cement Required to Lay 100 ft. of Special Deep Socket Pipe
(2-ft. Lengths).

Size of pipe, ins..	4	6	8	10	12	15	18	20	24
Cu. yds. Mortar :*									
Flush Joints..	.035	.050	.060	.075	.090	.130	.145	.170	.260
Overfilled " ..	.065	.100	.140	.170	.200	.300	.340	.440	.600
Bbls. Cement (1 to 1 mortar):									
Flush Joints..	.140	.200	.240	.300	.360	.520	.580	.680	1.04
Overfilled " ..	.260	.400	.560	.680	.800	1.20	1.36	1.76	2.40
Bbls. Cement (1 to 2 mortar):									
Flush Joints..	.105	.150	.180	.225	.270	.390	.435	.510	.780
Overfilled " ..	.195	.300	.420	.510	.600	.900	1.02	1.32	1.80

To calculate the cost of cement per lineal foot of pipe line multiply the fraction of a barrel of cement (given in Tables XXI. and XXII.) by the price of cement in dollars per barrel. Thus, if cement is $2 per bbl., and the mortar is mixed 1 part cement to 1 part sand, and deep-socket pipe is to be used with overfilled joints, we find, from Table XXII., that a 6-in. pipe requires 0.4 bbl. cement. multiplying this 0.4 by 2, gives 0.8 ct. per lin. ft. as the cost of cement, when cement is $2 per bbl. Under these same conditions the cost of cement per lin. ft., for different sizes of pipe, is as follows:

Size of pipe, ins.......	4	6	8	10	12	15	18	20	24
Cement per ft., cents..	0.5	0.8	1.1	1.4	1.6	2.4	2.7	3.5	4.8

*The number of barrels of cement required to make 1 cu. yd. of mortar is given on page 253. I have assumed 4 bbls. per cu. yd. for 1 to 1 mortar, and 3 bbls. per cu. yd. for 1 to 2 mortar.

Cost of Hauling Sewer Pipe.—The weight of sewer pipe is given in Table XVIII., and if 2 tons (4,000 lbs.) are hauled per wagon load, a wagon will carry the following amounts of pipe at the costs given:

Size of pipe, ins.........	4	6	8	10	12	15	18	20	24
Lin. ft. per wagon.......	444	266	174	114	92	66	46	40	28
Cost of Hauling, cts., per lin. ft., per mile.......	0.10	0.15	0.25	0.40	0.5	0.7	1.0	1.1	1.6

The cost of hauling is based upon wages of $3.50 a day for team and driver, and 16 miles traveled per day. It is assumed that enough men are provided at both ends of the haul to load and unload the wagon rapidly enough to leave the team time to cover its 16 miles, or that extra wagons are provided for each team. The cost of hauling 12-in. pipe, it will be seen, is ½-ct. per lin. ft. per mile. This does not include the cost of loading and unloading the pipe, which is practically as much more as the cost of hauling it one mile. Thus for 12-in. pipe, the cost of loading and unloading is ½-ct. per lin. ft., and to this must be added the cost of hauling at the rate of ½-ct per lin. ft. per mile of distance from the freight yard to the sewer. In other words, to calculate the cost of loading and hauling pipe, determine the actual number of miles from the freight yard to the sewer and add 1 mile (to cover the cost of loading and unloading), then multiply by the cost of hauling given in the table. For example, if the actual haul is 1½ miles, then, by the rule, add 1 mile, which makes 2½ miles. If the pipe is 10-in. pipe, the table gives us 0.4 ct. per ft. per mile, which multiplied by the 2½ miles gives 1 ct.

Cost of Laying Sewer Pipe.—With two laborers furnishing pipe and mortar to two pipe layers, the cost of laying and calking vitrified pipe need not exceed the following rates:

Size of pipe ins....	4	6	8	10	12	18	20	24
Cts. per lin. ft......	¾	1	1½	2½	3¼	6½	8	10

The wages are assumed to be $2.25 for each pipe layer, and $1.75 for each helper. Where men are working very hard, under favorable conditions, the costs may be 30% less than those above given. These costs do not include

trenching or backfilling, but do include tamping some earth around the bottom and sides of the pipe, preparatory to backfilling.

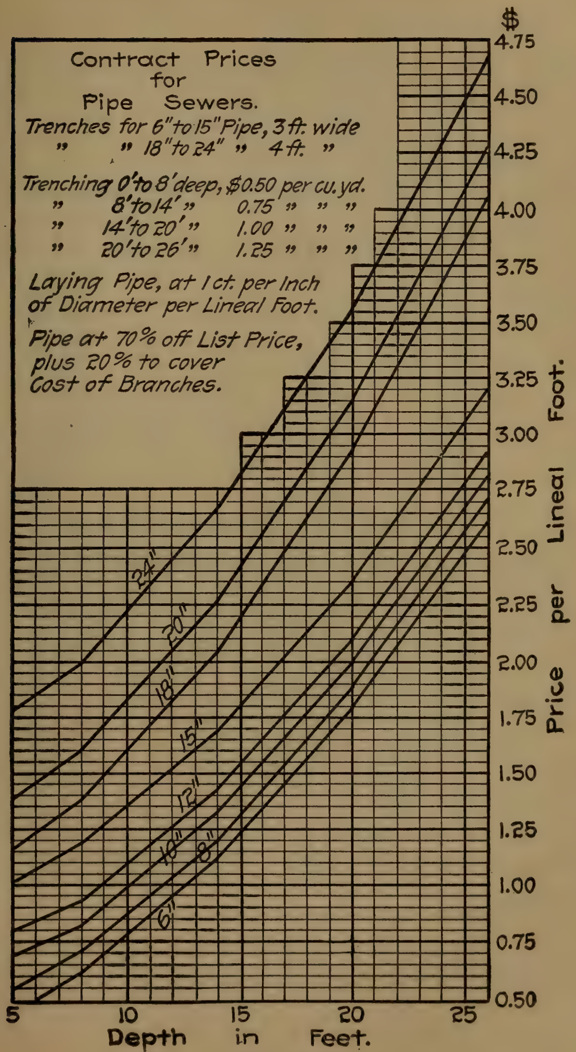
Diagram Giving Contract Prices of Sewers.—The diagram, Fig. 25, is one that I have prepared from data given by Mr. G. M. Warren, based upon contract prices for about 60 miles of sewer work in Newton, Mass., and covering a period of four years, 1891-1895. The wages of common laborers were $1.50 for 10 hrs.

The prices for trenching include excavating, sheeting and backfilling in earth; and do not relate to work in rock or quicksand.

The price of 1 ct. per inch of diameter of pipe per lin. ft. laid, includes hauling of pipe, labor of laying, and cement for joints.

The price of pipe is 70% off the list price given in Table XVIII., plus 20% to cover the cost of branches which are placed 25 ft. apart. For example, the list price of 12-in. pipe is $1.00; and with 70% discount the price becomes 30 cts. Now, 20% of 30 cts. is 6 cts., which approximately covers the extra cost of branches spaced 25 ft. apart, so that the total cost of the pipe for a 12-in. pipe line is 30 cts. plus 6 cts., or 36 cts. To this is added 12 cts. (1 ct. for each 12 ins. of diameter) to cover the price of "laying," making a total of 48 cts., exclusive of trenching. The first 8 ft. in depth of trench are dug at a price of 50 cts. per cu. yd. The next 6 ft. below are dug at a price of 75 cts. per cu. yd., and the price for each succeeding 6-ft. lift is 25 cts. higher per cu. yd. than the preceding lift. This is based upon the assumption that trench machines are not used, and that the earth is raised in 6-ft. lifts.

To show how to use the diagram, an example will serve. Suppose it is desired to know the contract price for a 12-in. sewer in a trench 15 ft. deep. Start at the bottom of the diagram on the line marked 15, and follow the line up until it meets the sloping line marked 12". Then starting from this intersection, follow the straight line across the page to the right until the side of the diagram is reached, when it will be seen that the intersection is just one division above $1.50; and, as each division is equal to 5 cts.,



Contract Prices
for
Pipe Sewers.
Trenches for 6" to 15" Pipe, 3 ft. wide
" " 18" to 24" " 4 ft. "
Trenching 0' to 8' deep, $0.50 per cu. yd.
" 8' to 14' " 0.75 " " "
" 14' to 20' " 1.00 " " "
" 20' to 26' " 1.25 " " "
Laying Pipe, at 1 ct. per Inch of Diameter per Lineal Foot.
Pipe at 70% off List Price, plus 20% to cover Cost of Branches.
24"
20"
18"
15"
12"
10"
8"
6"
$
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
Price per Lineal Foot.
5
10
15
20
25
Depth in Feet.

FIG. 25.

the price is $1.55 for a 12-in. pipe in a 15-ft. trench. This price includes contractor's profits.

Cost of 8-in. Sewer at Ithaca, N. Y.—In Engineering News, Aug. 20, 1896, Mr. H. N. Ogden, C. E., gives the following costs of trenching and laying 8-in. sewer pipe in Ithaca, N. Y.: The column of labor cost is based on daily wages of $1.35 for laborers, $1.50 for pipe layers, and $2 for foreman. Mr. Ogden has kindly informed the writer

Name of street	Length laid.	Depth of trench in ft.	Material.	No. of day's work	Cost of labor. Total	Per ft.
Wheat	1,134	5.3	1	4	$126.50	$0.11
Corn	1,504	5.8	2	5	200.70	.12
Washington	398	4.9	3	1½	49.50	.12
Titus	1,391	6.8	4	4½	318.90	.23
Plain	1,332	5.9	5	7	209.00	.16
Buffalo	597	6.7	6	4	108.25	.18
Fayette	984	5.6	7	4	195.05	.20
Centre	1,334	6.8	8	7	347.00	.26
Green	1,919	5.7	9	11	418.85	.22
Clinton	2,403	5.4	10	11	519.85	.22
Albany	1,431	5.0	11	9	319.50	.22
Geneva	1,323	5.3	12	7	373.47	.28
Cayuga	1,413	6.3	13	10	468.25	.33

[1]Wet clay; water 3 ft. down, bailed out.
[2]Wet clay; water 3 ft. down, bailed out, occasional bracing.
[3]Wet clay.
[4]Loam over wet clay; water 6 ft. down; occasional bracing.
[5]Wet clay; water 5 ft. down; diaphragm pump; occasional bracing.
[6]Clay and gravel; much water in places; pump; braced.
[7]Wet clay; water 4 ft. down; occasional bracing and pumping.
[8]Wet clay; water 3 ft. down; 1 diaphragm; occasional bracing.
[9]Half clay, half gravel; half close sheeted; underdrain pumps.
[10]Wet clay, some gravel pockets; 1 pump; some bracing.
[11]Gravel containing water at 5 ft.; pump; half sheeted.
[12]Sheeting and pumping entire; water at 5 ft.
[13]Loose gravel; brick pavement removed; half braced and half sheeted.

that the working day was 10 hours long. Teams were paid $3.50, masons on manholes $3.50 and masons' helpers, $1.50, 8-in. sewer pipe cost 12½ cts. per ft. Natural cement, at 95 cts. per bbl., laid 120 to 243 ft. of pipe per bbl. (Doubtless neat cement mortar was used.) The work was by contract, and not all under the same foreman; hence the variation in cost shown in the table.

Cost of a 12-in. Pipe Sewer, Menasha, Wis.—In 1903, some pipe sewers were built in Menasha, Wis., by day labor. I am indebted to Mr. S. S. Little for the following data: There were 2,200 ft. of trench, about half of which was for 12-in. pipe and half for 15-in. pipe. The depth of trench

ranged from 7½ to 10 ft., averaging 9 ft., and the width was 2 ft. The material was solid red clay. Wages paid were \$1.75 per 10-hr. day. Some team work, at \$3.50 a day, was used in scraping in the backfill. The labor of trenching laying pipe, and back filling averaged 37 cts. per lin. ft. of trench.

Cost of 8-in. to 18-in. Sewers at Cardele, Ga.—In Engineering News, March 30, 1893, Mr. Geo. G. Earl, C. E., gives the cost of some pipe sewer work at Cardele, Ga. Wages were 80 cts. to \$1 per day for labor (presumably negroes) and the foreman received \$70 a month.

Size of pipe.	Depth of cut in ft.	Length in ft.	Cost of labor, cts. per ft.	Cost of foreman, cts. per ft.
8 inches..............	5.9	1,185	14.1	1.0
8 "	7.0	3,090	22.8	1.9
8 "	8.0	900	33.8	1.9
8 "	11.2	487	35.2	5.8
10 "	7.0	225	26.7	....
10 "	7.1	298	35.5	1.6
12 "	5.4	1,044	27.0	1.1
18 "	6.7	963	33.5	1.7
18 "	10.6	867	79.2	4.0

The "Cost of Labor" given in the fourth column includes trenching, pipe laying and backfilling.

In building 2.6 miles of sewer (2 miles of which were 8-in.) and 35 manholes, the total cost was:

Labor	\$3,867	Brick	\$252
Masons and helpers..	462	Cement	166
Sundries	17	Hauling	82
Foreman	266	Manhole covers	289
Supervision	1,000	Tools and incidentals..	561
Pipe	2,635		
		Total	\$9,596

Cost of Sheeting at Peoria, Ill.—On a trench 13 ft. wide × 45 ft. deep, at Peoria Ill., sheeting in 16-ft. lengths cost as follows for labor:

2 men on top, at \$2	\$4
2 men setting sheeting, at \$2.50	5
8 men driving sheeting, at \$1.50	12
8 men pulling sheeting, at \$1.50	12
2 men moving lumber ahead, at \$1.50...............	3
Total daily wages of gang	\$36

This gang sheeted 12 lin. ft. of trench per day at a cost of $3 per lin. ft., all work being by hand; this is equivalent to 6⅔ cts. per lin. ft. of trench for each foot of depth. If 2-in. sheet plank were used, there were 192 ft. B. M. of sheet plank per lin. ft. of trench and probably 38 ft. B. M. of stringers and braces, say 230 ft. B. M. per lin. ft. From which we see that driving and pulling sheeting, including bracing, cost for labor about $13 per M. (= 1,000 ft. B. M.) at the rate of wages above given, which is a high cost.

The cost of exactly the same kind of work, using an Adams' trench machine with steam power for driving and pulling the sheeting, was as follows:

2 timber men on top, at $2	$4.00
2 men setting, at $2.50	5.00
1 man operating driver	2.00
2 helpers, at $1.50	3.00
1 man pulling	2.00
2 helpers, at $1.50	3.00
1 engineer	2.00
1 man moving lumber ahead	1.50
Coal, oil, steam hose and repairs	2.50
Total	$25.00

Twelve lineal feet of trench, 45 ft. deep, were timbered per day at this cost of $25, or at $2.08 per lin. ft., which is practically ⅔ the cost by hand above given, and in addition the wear of the sheet plank was less than with hand driving.

The following cost of sheeting is for hand work, trench being 12 ft. wide × 35 ft. deep:

2 timber men on top, at $2	$4.00
1 man setting	2.50
6 men driving, at $1.50	9.00
4 men pulling, at $1.50	6.00
1 man moving lumber	1.50
Total	$23.00

At this cost, 13 lin. ft. of trench were sheeted per day, or at the rate of $1.77 per lin. ft.

Smaller trenches, 8 ft. to 16 ft. deep in sand, cost from 10 to 25 cts. per lin. ft. for labor of sheeting with 2 × 8-in. hemlock. Stringers in trenches 35 ft. or more deep were 8 × 8 ins. yellow pine, with 6 × 8-in. white pine braces. In trenches of less depth 6 × 6-in. hemlock stringers and braces were used. The above costs do not include wear and tear on timber. Some sewer contractors figure on using hemlock sheeting about 4 times, with hand-driving, before it is worn out.

Cost of 12-in. Sewers in Toronto, Canada.—A large number of 12-in. pipe sewers were built by day labor for the city of Toronto in 1891, at the following costs:

Number of jobs.	Average depth.	Soil.	Length, feet.	Man-holes.	Catch-basins.	Connec-tions.	Cost per foot.
3......	10′ 10″	Quicksand	1,041	5	6	15	$1.95
9......	11′ 2″	Clay	4,427	19	21	240	1.27
1......	18′ 0″	Blue clay	650	3	..	..	2.11
1......	12′ 1″	"	180	1	..	15	2.20
1......	11′ 6″	"	251	..	..	4	2.41
1......	8′ 1″	"	800	3	4	29	1.33
1......	9′ 9″	"	483	4	2	24	1.78
1......	11′ 2″	Clay loam	430	2	2	13	0.96
1......	10′ 8″	"	357	3	..	17	1.90
1......	11′ 0″	Hardpan	320	2	2	18	1.28
1......	11′ 3′	Sand	535	3	2	5	1.50
21......	11′ 4″	Av. of above	9,474	45	39	380	1.51

Note.—The cost per ft. includes all materials, labor and inspection of work. It also includes the manholes and catch-basins, and the Y-connections. The 12-in. pipe cost 22 cts. per ft.; brick was $8.50 per M. Laborers were paid 15 cts. per hr., and a few special men were paid 18 cts. per hr.; bricklayers were paid 40 cts. per hr.

Brick Sewer Data.—Brick sewers are either "circular" or "egg-shape." In either case the upper part of the sewer is called the "arch," and the lower part is called the "invert." The depth of a brick sewer, as given on profiles, is the depth from the surface of the street to the inside of the bottom of the sewer, so that the thickness of the sewer invert should be added to secure the full depth of the trench. The thickness of a brick sewer is usually expressed in "rings." A "one-ring" sewer is made one brick thick; that

is, 4 ins. thick plus the cement plaster which is usually ½-in. thick; so that a one-ring sewer is 4½ ins. thick. A two-ring sewer is two bricks, or 9 ins. thick. A three-ring sewer is three bricks, or 13½ ins. thick.

The size of a sewer is denoted by its inside diameter.

Brick sewers, like pipe sewers, are usually paid for by the lineal foot of sewer including trenching; but it is desirable always to calculate the brickwork in cubic yards. Table XXIII. gives the number of cubic yards of brick masonry per lineal foot of circular sewer.

For intermediate sizes interpolate between the values given in the table.

To calculate the number of cubic yards per lineal foot of any circular sewer, proceed as follows: Add the inside diameter in feet to the thickness of the sewer in feet; this gives the "average diameter." Multiply this "average diameter" by 3 1-7: then multiply the quotient by the thickness of the sewer in feet and divide by 27.

For example, a 5-ft. sewer has walls 9 ins. thick (it is a "two-ring" sewer); and, as 9 ins. = ¾ ft., we have by the rule: 5 + ¾ = 5¾ as the "average diameter;" then 5¾ × 3 1-7 × ¾ ÷ 27 = ½ cu. yd. per lin. ft.

Sewer bricks are of a better quality than common building bricks, and usually cost $1 per M more than common bricks. Ordinarily about 500 bricks are required per cubic yard. About 2% must be added to cover the wastage.

Since the joints are V-shaped, and since the inside of the sewer is usually plastered, more mortar is required than in plain brickwork. About 0.35 to 0.4 cu. yd. of mortar is required per cu. yd. of brick masonry. The number of barrels of cement required to make 1 cu. yd. of mortar is given on page 253.

In building 5-ft. circular sewers at Lawrence, Mass., in 1886, 1 part natural cement to 1½ parts sand was used; and it required 2½ bbls. of cement per thousand bricks.

At Newton, Mass., a 24 × 36-in. egg-shaped sewer required 1.5 bbls. of cement per cu. yd., the mortar being mixed 1:1½. There were 509 bricks per cu. yd. of sewer masonry, not including the waste; and 520 bricks including waste.

At Los Angeles, two-ring 40-in. circular sewers required 0.4 bbl. Portland cement per lineal foot of sewer, which is

equivalent to 1.12 bbls. cement per cu. yd. of brick masonry. The mortar was 1 part cement to 2 parts sand.

Mr. Desmond Fitzgerald gives the following as averages of cost of brick sewer work done by certain contractors at Boston, prior to 1894.

	Per cu. yd.	
Labor	$2.89	$3.40
Brick (560 to 580 per cu. yd.)	5.48	5.30
Sand	0.30	0.40
Natural cement, 1.27 bbls.	1.35	1.50
Centers	0.23	.20
Miscellaneous	0.19	.20
Total per cu. yd.	$10.44	$11.00

The first example is the cost of a well handled job of 1,300 cu. yds. of brick masonry. The second example is the average of several jobs. Brick cost $9.50 per M; and natural cement $1.13 per bbl. The mortar was probably mixed

TABLE XXIII.

Brick Masonry in Circular Sewers, Cu. Yds. per Lineal Ft.

Diameter Ft.	Ins.	One-Ring (4½ ins.)	Two-Ring (9 ins.)	Three-Ring (13½ ins.)
2	0	0.103	0.240	......
2	3	.114	.261	......
2	6	.125	.280	......
2	9	.136	.305	......
3	0	.147	.327	......
3	3	.158	.349	......
3	6	.169	.371	......
3	9	.180	.393	......
4	0	.191	.415	......
4	3	.202	.436	......
4	6	.213	.458	......
4	9	.223	.480	......
5	0	.234	.501	.802
5	3	.245	.523	.834
5	6	.256	.545	.867
5	9	.267	.567	.900
6	0	.278	.589	.933
6	3	.....	.611	.966
6	6	.....	.633	1.000
6	9	.....	.655	1.031
7	0	.....	.677	1.063
7	6	.....	.720	1.128
8	0	.....	.763	1.193
8	6	.....	.807	1.260
9	0	.....	.851	1.325
9	6	.....	.895	1.390
10	0	.....	.938	1.456

TABLE XXIV.

Brick Masonry in Egg-shaped Sewers, Cu. Yds. per Lineal Ft.

Dimensions Ins.	One-Ring (4½ ins.)	Two-Ring (9 ins.)	Three-Ring (13½ ins.)
12 x 18	0.071	0.176	.....
14 x 21	.081	.194	.....
16 x 24	.090	.212	.....
18 x 27	.099	.231	.....
20 x 30	.108	.249	.....
22 x 33	.117	.267	.....
24 x 36	.126	.286	.....
26 x 39	.136	.304	.....
28 x 42	.145	.322	.....
30 x 45	.154	.341	....
32 x 48	.163	.359	.....
34 x 51	.172	.374	.....
36 x 54	.182	.396	.....
38 x 57	.191	.414	.....
40 x 60	.200	.433	0.698
42 x 63	.....	.451	.725
44 x 66	.....	.469	.753
46 x 69	.....	.488	.781
48 x 72	.....	.506	.808
50 x 75	.....	.524	.836
52 x 78	.....	.543	.863
54 x 81	.....	.561	.891
56 x 84	.....	.579	.918
58 x 87	.....	.598	.946
60 x 90	.....	.616	.973

1 part cement to 1½ parts sand. Wages of bricklayers were probably 50 cts. per hr., and helpers 15 to 20 cts. per hr.

Bricklayers on sewer work often receive abnormally high wages. In some cities the labor unions have forced up the price to $1 per hour! In such cases a bricklayer is usually required to lay not less than 3,000 bricks a day; and I have known as high as 5,000 bricks to be laid by a very skilful and rapid layer.

The dimensions of egg-shaped sewers are given in terms of the inside diameter of the upper arch, and the inside height of the sewer; thus a 30 × 45-in. sewer, is one having an upper arch 30 ins. inside diameter and an inside height of 45 ins. The Phillips Metropolitan Standard (English) egg-shaped sewer has an inside height which is 1½ times the diameter of the arch. Calling the diameter of the arch d, the other dimensions are:

Radius of invert	¼ d
Radius of side	1½ d
Height	1½ d
Area of waterway	1.15 d^2
Perimeter	3.96 d

The first dimension given in the first column of Table XXIII. is d. The table gives the number of cubic yards of masonry per lin. ft. of egg-shaped sewer.

Cost of Brick Manholes.—The walls of brick manholes are generally 8 ins. thick up to 12 ft. in depth, and 12 ins. thick below. The cross-section of manholes is usually elliptical, 3 ft. × 4½ ft., up to the neck of the manhole which is circular and narrows down to about 24 ins. in diameter. The cast iron ring and cast iron cover weigh from 375 lbs. to 650 lbs., the lighter weight being used in village streets. A common weight for use in cities is 475 lbs. These "manhole heads" are carried in stock by manufacturers of sewer pipe, and are listed in their catalogues. The following is the actual cost of a manhole built by day labor for a Western city:

2,000 brick at $6	$12.00
475-lb. ring and cover, at 2 cts	9.50
2⅔ bbls. Louisville cement, at 75 cts	2.00
1 cu. yd. sand	1.50
24 hrs. brick layer, at 55 cts	13.20
24 hrs. helper, at 18¾ cts.	4.50
Total	$42.70

It will be noted that the mason averaged less than 700 bricks per 8-hr. day, which indicates that he realized that he was working for a city and not for an individual. However, small jobs like manhole-work are apt not to be handled with rapidity. Consult, for comparison, the data on manhole work given on page 456.

Cost of Pipe and Brick Sewers, St. Louis.—Mr. Curtis Hill gives the following data, which are averages of work done by contract during three years, April, 1901, to April, 1904. The work consisted in building 40 miles of pipe sewers, 12 to 24 ins. diam., and 13 miles of egg-shaped (18 × 27-in. to 48 × 60-in.) and circular (60 to 108-in.) sewers. The egg-shaped sewers were 9 ins. thick; the circular sewers were 13 ins. thick. The excavation was, for the most part, in stiff clay, only a small amount of quicksand occurring. Trench excavators were not very suc-

cessful, because the "joint clay" caved in if not well braced as fast as excavated. The Chicago Sewer Excavator, however, made the best records made with trench excavators. Potter trench machines were largely used for the smaller trenches, and cableways for the larger trenches. The Potter machine consists of a movable trestle, and a bucket car that rides on tracks on top of the trestle bents. This car is moved back and forth by a stationary hoisting engine, which also hoists the buckets. The legs of the trestle span the trench and are provided with wheels that rest on rails.

The following table gives the actual average cost to the contractors, including foremen and superintendence, but not including interest and depreciation of plant, insurance of men, and office expenses.

COST OF PIPE AND BRICK SEWERS, ST. LOUIS

Brick Sewers.	Earth Excavation.			Brick Masonry.			
	Cut in feet to sub-grade.	Cu. yds. per laborer per hour.	Cost per cu. yd.	Cu. yd. per mason per hour.	Cost of labor and mason per cu. yd.	Cost of material per cu. yd.	Total cost per cu. yd.
12½′ x 15′*	30	......	......	1.18	$1.71	$6.13	$7.84
9′ circular†.....	26	1.0	$0.36	1.00	1.87	6.13	8.00
6′ circular†.....	17	0.8	0.40	0.97	1.75	6.30	8.05
5′ circular†.....	16	0.8	0.40	0.95	1.80	6.30	8.10
2′ x 3′‡.........	11	......	......	0.80	2.40	6.10	8.50

* Method of excavation was steam shovel followed by a cable-way. The lumber bracing cost $3.60 per running foot of sewer.

† Potter trench machine used.

‡ No trench machine used.

The "cu. yds. per laborer per hr." means the number of cubic yards excavated and loaded into buckets by each laborer actually engaged in digging. The average of all the work, including pipe sewers, was about 9 cu. yds. excavated per man per 10-hr. day.

On pipe sewer trenches where no machinery was used the cost of earth excavating was as follows:

Size of pipe, ins.	Depth in ft.	Cost per cu. yd.
24......................	15	$0.50
21......................	16	0.50
21......................	7	0.35
18......................	8	0.35
15......................	16	0.55

It cost 90 cts. per cu. yd. to excavate loose rock in the trenches 15 and 16 ft. deep; and $3.80 per cu. yd. to excavate solid rock.

"Four men, the bottom man and his helper, with two men handling and lowering the pipe, laid 21-in. and 24-in. pipe at the rate of sixteen lineal feet per hour. Three men will lay the same amount of 15-in. or 18-in. pipe in the same time. Including the material for jointing, the cost of laying pipe is 10 cts. per lin. ft.

"A good sewer brick mason will lay from 400 to 500 bricks per hr. There is one case where four masons, working on a 6½-ft. brick sewer, each averaged 600 bricks per hr., and kept it up for several days, but this is far above the average."

The average contract prices for the three years (1901-4) was as follows:

12-in. pipe, per lineal foot	$0.45
15-in. pipe, per lineal foot	0.55
18-in. pipe, per lineal foot	0.80
21-in. pipe, per lineal foot	1.00
24-in. pipe, per lineal foot	1.60
Pipe junctions, extra, each	1.50
Slants for brick sewers, each	0.65
Earth excavation, per cubic yard	0.55
Loose rock excavation, per cubic yard	1.60
Solid rock excavation, per cubic yard	4.00
Concrete, per cubic yard	6.50
Brick masonry, per cubic yard	9.40
Vitrified brick masonry, per cubic yard	12.20

It will be noted that the excavation was paid for as a separate item, and not included with the pipe or brick.

Mr. Hill informs me that on a recently completed brick sewer, requiring 287 days to build, two Potter machines and a cableway were used. There were 49,918 cu. yds. of Class "A" excavation (earth), 6,629 cu. yds. of class "B" (loose rock), and 33 cu. yds. of Class "C" (solid rock). There were 2,303 lin. ft. of 9-ft. sewer, 3,240 lin. ft. of 8-ft. sewer, 254 lin. ft. of 7-ft. sewer, 1,607 lin. ft. of 5½-ft. sewer, and 1,203 lin. ft. of 4 × 5-ft. sewer. These required 8,177 cu. yds. of hard brick masonry and 723 cu. yds. of

COST OF A WEEK'S SEWER WORK ON FOUR JOBS

Kind of Trench Mach.		Potter		Potter		Carson		None	
	Wages per hour	Job No. 1		Job No. 2		Job No. 3		Job No. 4	
		Hrs.	Wages	Hrs.	Wages	Hrs.	Wages	Hrs.	Wages
Foreman	$0.50	54	$27.00	54	$27.00	54	$27.00	9	$4.50
Laborer	.22½	1,089	245.02	1,000	225.00	640	144.00	126	28.35
Bottom man	.30	50	15.00	47	14.10	54	16.20	9	2.70
Water boy	.15	54	8.10	54	8.10	54	8.10	9	1.35
Team	.50	54	27.00	......	....	......	....	......	....
Watchman	.25	63	15.75	......	....	54	13.50	......	....
*Machine	1.50	64	81.00	54	81.00	54	81.00	......	....
Total for excavation		$418.87		$355.20		$289.20		$36.90	
Total cu. yds. "		980		600		407		120	
Cubic yards per hour per man		0.9		0.6		0.64		0.95	
Cost per cubic yard		$0.43		$0.60		$0.71		$0.31	
Depth of trench, ft.		19¼		23		18		Shallow	
Kind of soil		Sandy		Stiff earth and clay		Stiff earth, fire clay and 30% loose rk.		Black loam	
Size of sewer		3 x 4 ft.		2½ x 3½ ft.		18-in. pipe		21-in. pipe	
Length of sewer, ft.		300		154		244		108	
Brick Mason	$0.75	104	$78.00	68	$51.00				
Helper	.25	104	26.00	84	21.00				
Mortarman	.27½	104	28.60	84	23.10				
Total			$132.60	......	$95.10	4¼ lin. ft. of pipe (double strength) laid per hour per bottom man (or pipe layer), whose wages are 30 cents per hour		12 lin. ft. of pipe per hour per bottom man. Trench shallow, no scaffolding or bracing	
Cu. yds. brick masonry		112		61					
Cu. yds. per mason per hr.		1.08		0.90					
Cost of labor per cubic yard masonry		$1.20		$1.56					
450 brick at $8.25 M		3.71		3.71					
0.7 bbl. cement (1-3 mort.) at $1.50		1.05		1.05					
0.2 cu. yd. sand, at $1.10		0.22		0.22					
Total per cubic yard brick masonry		$6.18		$6.54					

*A trench machine is rented for $125 per month, and burns 15 bushels of coal per 9-hour day. When the rental and fuel costs are added to the wages of engineman and fireman, the total cost is $1.50 per hour.

vitrified brick masonry. The excavation ("A," "B" and "C") cost 68 cts. per cu. yd., of which 11½ cts. was the cost of the trench machines. The total cost of this trench excavation (56,580 cu. yds.), including labor of bracing and backfilling, was as follows:

Foreman, 6,400 hours, at 50 cts.	$3,200.00
Laborer, 87,000 hours, at 22½ cts.	19,575.00
Bottom-man, 6,360 hours, at 30 cts.	1,908.00
Waterboy, 3,800 hours, at 15 cts.	570.00
Team, 10,450 hours, at 50 cts.	5,225.00

Watchman, 4,800 hours, at 25 cts..............	$1,200.00
Machine, 4,400 hours, at $1.50	6,600.00
Total	$38,278.00

Most of the trenches require bracing, the timber for which costs 2 cts. to 10 cts. per cu. yd. of excavation, which is not included in the above. Yellow pine costs $18 per M.

The wages of foremen, waterboys and watchmen are all charged against excavation, and no part against masonry.

The cost of laying the brick masonry was as follows:

Masons, 9,400 hrs., at 75 cts....................	$7,050.00
Helpers, 1,400 hrs., at 25 cts....................	3,500.00
Mortarmen, 10,750 hrs., at 27½ cts............	2,956.25
Total for 8,900 cu. yds., at $1.52...........	$13,506.25

The masons averaged 422 bricks per hr., or 3,376 bricks per 8-hr. day.

Cost of Large Brick Sewers, Denver, Col.—Mr. W. W. Follett gives the following data on brick and concrete sewers built by day labor in Denver, Col.: Work was begun Aug., 1894, and finished June, 1895. Work was carried on in the winter which added somewhat to the cost. The wages paid were high and the hours of labor short. The men were considered to be efficient. The following were the number of day's work performed and the wages per 8-hr. day:

726 days, foremen, at $3.33⅓ to $5.
1,398 days, stone masons, at $3.60.
1,491 days, brick masons, at $4.00.
385 days, watchmen, blacksmiths, and timbermen, at $2.50.
8,115 days, labor, at $2.00.
7,628 days, labor, at $1.75.
363 days, waterboys, at $1.00 to $1.25.
2,150 days, team with driver, at $3.50.
252 days, enginemen and pumpers, at $3.00.

Note.—Sec. 1 was built in filled ground containing city refuse. The original ground was about level with the invert, and had been filled with 2 to 5 ft. of refuse. The

COST OF BRICK AND CONCRETE SEWERS, DENVER, COLO.

	Sec. 1.	Sec. 3.	Sec. 5.	Sec. 6.	Sec. 7.	Sec. 8.	Sec. 9.	Secs. 7, 8, 9.
Diameter, ins	94	70	70	70	77	77	77	77
Length, ft	2,394	1,714	211	503	947	1,396	1,094	3,437
Depth of trench, ft	......	......	......	11.0	11.0	12.5	14.0	......
Cu. yds. earth excavation, per ft	3.33	1.25	1.2	3.0	4.0	5.5	7.0	......
" rock excavation, per ft	......	......	1.5	1.4	1.4	......	......	......
" backfill " "	2.4	3.2	2.7	4.4	5.4	5.5	7.0	......
" concrete " "	0.395	0.349	0.150	......	......	......	......	......
" stone masonry excavation, per ft	1.800	1.250	......	......	......	......	......	......
" brick " " "	0.753	0.588	0.583	0.885	0.967	0.967	0.967	......
Cost per lin. ft.:								
Excavation	$0.891	$0.377	$1.236	$1.412	$2.058	$1.620	$1.766	$1.787
Pumping—draining	0.743	0.595	......	......	0.078	0.484	0.282	0.308
Concrete base	1.925	1.645	0.635	......	......	......	......	......
Stone cradle	8.128	6.134	......	......	......	......	......	......
Brickwork	6.443	5.761	5.722	8.324	9.332	9.203	9.396	9.300
Backfilling	0.832	0.842	0.347	0.223	0.357	0.301	0.822	0.482
Engineering	0.715	0.663	0.916	0.572	0.500	0.463	0.420	0.460
Tools	0.424	0.320	0.381	0.150	0.097	0.100	0.140	0.112
Watchman, etc	0.090	0.178	0.173	0.134	0.145	0.121	0.130	0.131
Total	$20.191	$16.515	$9.410	$10.815	$12.567	$12.292	$12.956	$12.580

NOTE.—Sec. 1, was built in filled ground containing city refuse. The original ground was about level with the invert, and had been filled with 2 to 5 ft. of refuse. The bottom of the trench was 2 to 4 ft. below the level of a river near by, so that there was much pumping. The backfill was largely hauled in with wagons.

bottom of the trench was 2 to 4 ft. below the level of a river near by, so that there was much pumping. The backfill was largely hauled in with wagons, as the material from the trench was not a suitable backfill. The sewer had a concrete base 8 ins. thick and 16 ft. wide, on top of which was a stone cradle. The invert was a single ring of brick, and the arch was three rings.

Sec. 3 was nearly all in good ground, but there was water all along it. The cross-section of the sewer was the same as in Sec. 1, except with less diameter, giving about 80% as much material.

Sec. 6 contained rock for its full length, but the rock was very soft, being in places hardly more than indurated clay. The trench averaged 11 ft. deep, and was timbered all along. No water was encountered. The sewer was three-ring brick.

Sec. 7 was similar in every way to Sec. 6, except that a loose sand overlaid the rock.

Sec. 8 was in gravel containing much water. The cut averaged 12½ ft. deep.

Sec. 9 was in fine, loose sand heavily charged with water. The average cut was 14 ft. deep.

The concrete foundations were made 1:3:6 Portland cement and crushed, unscreened sandstone. The stone was estimated on a basis of 2,500 lbs. per cu. yd. Concrete was hand mixed and delivered in wheelbarrows. The average cost of 1,545 cu. yds. of concrete was as follows:

0.732 bbl. cement	$2.543
0.754 cu. yd. stone	1.409
0.424 cu. yd. sand	0.148
Water	0.007
Labor ($1.75 an 8-hr. day)	0.703
Total per cu. yd.	$4.810

The stone cradle was built of a soft sandstone which broke out square in the quarry so that little hammering was required in the trench. It was bought by the ton. Louisville (natural) cement, weighing 265 lbs. per bbl., was used in a 1 : 2 mortar. The average cost (not in-

cluding engineering) of 6,438 cu. yds. of this stone cradle was as follows:

1.297 cu. yds. of rubble	$1.975
0.875 bbl. natural cement	1.261
0.305 cu. yd. sand	0.130
Water	0.005
Labor (masons, $3.60, laborers, $2.00, for 8 hrs.)	1.284
Total per cu. yd.	$4.655

The invert brick ring of Sec. 3 was laid in 1 : 3 Portland mortar, and the same mortar was used in plastering. On Secs. 1, 3 and 5 a 1 : 2½ Louisville mortar was used; and on Secs. 6, 7, 8 and 9, a 1:3 Louisville throughout. One foreman handled 18 brick layers divided into three gangs, the total number of his force, including helpers and laborers, being 80 men. The amount of cement per cubic yard of brickwork, by sections, was as follows: Sec. 10, 0.835 bbl.; Sec. 3, 1 bbl.; Sec. 5, 1.07 bbls.; Sec. 6, 0.87 bbl.; Sec. 7, 0.937 bbl.; Sec. 8, 0.99 bbl.; Sec. 9, 0.876 bbl. The number of brick per cubic yard ranged from 431 on Sec. 3 to 450 on Sec. 6. The average cost of 6,702 cu. yds. of brickwork on all sections was as follows, per cu. yd.:

439 brick	$4.584
0.92 bbl. cement	1.953
0.41 cu. yd. sand	0.198
Miscellaneous	0.229
Labor	2.384
Total per cu. yd	$9.348

The labor cost ranged from $2 per cu. yd. on Secs. 1 and 3 to $2.95 on Sec. 9.

A neat form of steel centering was designed and used as follows: Light, 8-lb., dump-car rails were bent so as to form half-rings; the lower half-ring (or semicircle) being bent with the head of the rail facing out, and the upper half-ring with its head facing in, as shown in Fig. 26. A short piece of rail was laid with its flange against the flange of the lower half-ring and riveted. One of

these short pieces of rail was thus riveted at each end of the lower half-ring. Thus it was possible to butt the ends of the upper half-ring against these short pieces of rail riveted to the lower half-ring, and connect the two with fish-plates and bolts. In order to be able to "strike" (remove) these steel centers, a bevel-joint was made, as

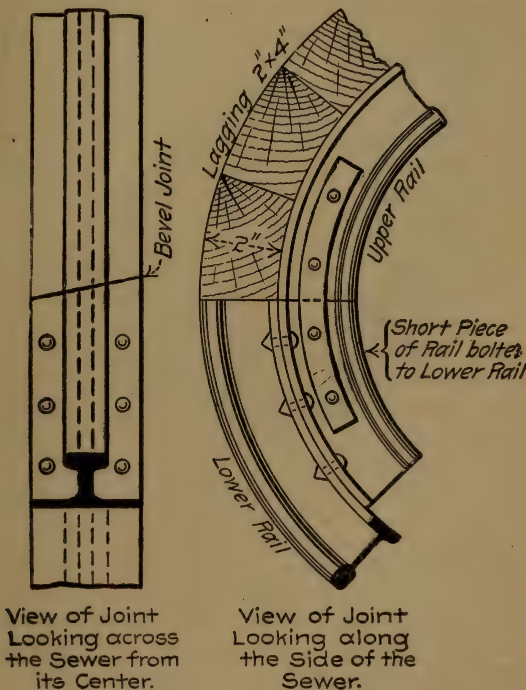


FIG. 26.

shown in the figure. This was done by sawing one end of the upper half-ring across on a bevel, and sawing a similar bevel on the end of the short piece of rail against which it butted. After the fish-plate bolts were removed, a blow of a hammer would readily knock the two half-rings apart at the bevel-joint. It will be noted that the 2-in. lagging was laid upon the flange of the upper half-ring, no lagging

being used on the lower half-ring, as the invert was built of brick.

To hold the lagging to the upper half-ring, it was found best to make little iron clips, three of which were fastened to the underside of each 12-ft. stick of lagging, using two wood screws for each clip. The end of the clip slipped over the flange of the steel rail, but was not screwed or bolted to the rail, so that each stick of lagging was quickly removed by shoving it endwise. These steel centers or rings were placed 2 ft. 5 ins. apart, c. to c., so that 40 rings sufficed to set up centers for 96 ft. of sewer. Two men would take down, clean and set up 96 ft. of this centering in a day, making the cost of moving centers about 4 cts. per ft. of sewer. In building 8,290 ft. of sewers, three sets of steel centers and two sets of lagging were used, costing $775 for materials and labor of making, or 9.3 cts. per ft. of sewer, making a total cost of a little over 13 cts. per ft. of sewer for making and moving lagging and material. There were only three sets of rings because there were only three sizes of sewers, 70, 77 and 94-in.

Cost of a Concrete and Brick Sewer.—Mr. William G. Taylor, City Engineer of Medford, Mass., gives the following data of work done in 1902, by day labor for the city. Figure 27 is a cross-section of the sewer, which has a concrete invert and sides and a brick arch. The concrete was 1 : 3 : 6 gravel. The forms for the invert were made collapsible and in 10-ft. lengths. The two halves were held together by iron dogs or clamps. The morning following the placing of the concrete the dogs were removed and turnbuckle hooks were put in their places, so that by tightening the turnbuckle the forms were carefully separated from the concrete. The concrete was then allowed to stand 24 hrs., when the arch centers were set in place. These centers were made of ⅞ × 1½-in. lagging on 2-in. plank ribs 2 ft. apart, and stringers on each side. Wooden wedges on the forward end of each section supported the rear end of the adjoining section. The forward end of each section was supported by a screw jack placed under a rib 2 ft. from the front end. To remove the centers, the rear end of a small truck was pushed under the section about 18 ins.; an adjustable roller was fastened by a

thumb screw to the forward rib of the center; the screw jack was lowered allowing the roller to drop on a run board on top of the truck; the truck was then pulled back by a tail rope until the adjustable roller ran off the end of the truck; whereupon the truck was pulled forward drawing the center off the supporting wedges of the rear

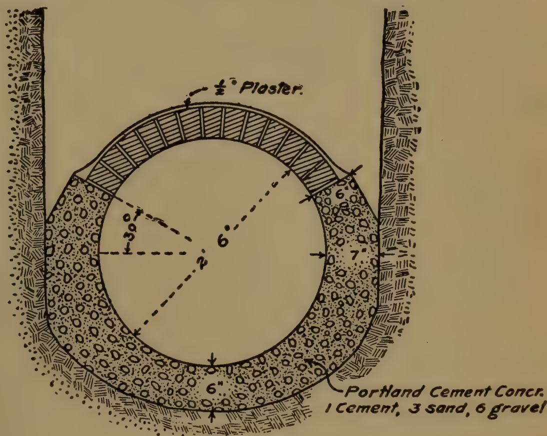


FIG. 27

section. In this manner not the least injury was done to the fresh concrete.

Each lineal foot of sewer required 1¼ cu. yds. of excavation; 4 cu. ft. of concrete, and 1 cu. ft. of brick arch. The sewer was 1,610 ft. long and was built by day labor, wages being $2 for 8 hrs. The material excavated was gravel and clay.

Excavation and backfill:	Per cu.yd.	Per lin. ft.
Excavation, labor, 25 cts per hr......	$0.339	$0.424
Bracing	0.026	0.032
Backfilling	0.168	0.210
Waterboy	0.017	0.021
Kerosene	0.009	0.011
Lumber	0.035	0.044
Total	$0.594	$0.742

Concrete masonry:	Per cu. yd.	Per lin. ft.
Portland cement, at $2.15 per bbl......	$2.292	$0.343
Labor mixing and placing............	3.017	0.452
Cost of forms	0.187	0.028
Labor screening gravel*	0.471	0.070
Carting	0.592	0.088
Miscellaneous	0.146	0.021
Total	$6.705	$1.002

Brick masonry:	Per cu. yd.	Per. lin. ft.
492 brick, at $8.50 per M	$4.182	$0.153
1⅓ bbls. cement,† at $2.25 per bbl......	3.026	0.111
Forms	0.408	0.015
Labor, mason	1.343	0.049
Labor, helpers	2.091	0.077
Carting	0.680	0.025
Incidentals	0.340	0.012
Total	$12.070	$0.442

*The gravel and sand were obtained from the excavation.
†This includes cement used in plastering the arch.

The cost of this 30-in. sewer was, therefore, $1.44 per lin. ft. exclusive of the excavation which cost 74 cts. per lin. ft. The cost of brickwork in manholes was $15.34 per cu. yd. It should be noted that wages were high ($2 per 8 hrs.) and that the work was done by day labor, thus making the cost higher than it would be to a contractor.

Cost of a Brick Conduit.—A conduit of horse-shoe shape, 7½ ft. in diameter, was built with a brick arch 8 ins. thick and a concrete invert lined with brick 4 ins. thick. The cost of the concrete work is given on page 360. The following relates only to the brickwork. Work was done by contract, in 1884, in Massachusetts. The cost of 960 M of brickwork was as follows:

Labor:	
Foreman, 39 days, at $5.00	$195.00
Laborers, 320 days, at $1.25	400.00
Laborers, 1,752 days, at $1.50................	2,628.00

Masons, 753days, at $4.90	$3,601.50
Carpenter, 4 days, at $2.50	10.00
Horse and car, 90 days, at $3.15	283.50
Miscellaneous labor	23.75
Materials:	
Brick, 960,000, at $8.40 per M..................	9,024.00
Cement, 315 bbls. Portland, at $3.20...........	1.008.00
Cement, 1,681 bbls. natural, at $1.26..........	2,118.06
Sand, 571 cu. yds., at $1.20....................	685.20
Plant:	
Boiler, 15 days, at $1.00	15.00
Pumps, 101 days, at $0.25	25.25
Cars and tools	79.00
Forms and centers	304.00
Coal, 12 tons, at $6.00	72.00
Office building	57.00
Total	$20,529.26
General expense, time keeper, watchman, etc. .	1,038.36
Grand total	$21,567.62

These 960 M of brick made 1,600 cu. yds. of masonry, or 570 bricks per cu. yd. About 5% were culled and rejected. It took 1.23 bbls. of cement per cu. yd. Masons each averaged 1,250 bricks per day, which was a poor average for men paid such high wages. The cost per cubic yard of this brick masonry was:

	Per cu. yd.
Masons laying, at 49 cts. per hr..................	$2.38
Laborers tending, including unloading, etc., at 15 cts. per hr.	2.07
Brick, 570 at $8.40 per M	5.59
Sand, 0.35 cu. yd., at $1.20	0.42
Cement, 1.23 bbls.	1.55
Forms	0.19
General expense and miscellaneous	1.05
Total per cu. yd.	$13.25

Cost of Tile Drains.—Clay tiles for drainage purposes are usually round in section, and are usually made in 1-ft. lengths. In soil that can be spaded, a special ditching spade should be used. The blade of this type of spade is narrow and very long (18 ins.), and strongly curved forward to give greater stiffness. With such a spade, a trench 5 ft. deep, and not more than 15 ins. wide at the top, can be dug. Trenches 3 ft. deep are 10 to 12 ins. wide on top, and are taken out in two spadings, or benches. The bottoms of the trenches are shaped so as to fit the tile, by using a tile hoe or scoop of proper shape, different widths being used for different sizes of tile. The tiles are laid by a man standing on the surface of the ground, using a tile hook for the purpose of placing the tiles in the trench. The trench is backfilled by a team dragging a plow provided with a long evener, so that there is one horse on each side of the trench.

In "Practical Farm Drainage," C. G. Elliott gives the following as the actual cost of draining an 80-acre farm in Illinois:

Tile.			Cost per lin. ft.			
Size, ins.	Lin. ft.	Depth, ft.	Tile, cts.	Laying, cts.	Total, cts.	Total.
3......	7,030	3	1.32	2.00	3.32	$233.40
4......	8,280	3½	2.00	2.00	4.00	331.20
5......	850	4	3.00	2.42	5.42	46.07
6......	2,700	5	4.00	3.66	7.66	206.82
7......	1,000	5	6.00	3.72	9.72	97.20
Total, 80 acres at $11.43 per acre....................						$914.69

The cost of "laying," as above given, includes the cost of digging the trench, laying the pipe and backfilling. The men were paid $2 a day, being skilled diggers and tile layers. The soil was a black loam 2½ ft. thick, under which was a yellow clay subsoil.

For tile up to 6 ins. diameter, Elliott estimates 1½ cts. per lin. ft. for labor of trenching 3 ft. deep and laying the tile; and he allows 0.3 ct. per lin. ft. for backfilling.

The manufacturers of tile do not have uniform list prices from which discounts are given. The following net prices are quoted (1905) for New York delivery in car-load lots:

Size of drain tile, ins.	Weight, lbs. per ft.	Net price per ft., cts.
2	3	1.45
2½	4	1.72
3	5	2.18
4	7	3.04
5	9	3.93
6	12	5.38
8	19	8.20
10	28	14.50
12	40	18.80

Tile drains are frequently used for road drainage. In such cases the trench is usually filled part way up with broken stone or gravel, the cost of which must be included in the bidding price per lin. ft. of drain. Tile collars to be used at joints are occasionally specified, but they are of questionable value, and are rarely used in land drainage. On roadwork done by the author, the cost of laying 4-in. tile in a trench was ¼ ct. per lin. ft., exclusive of digging the trench and filling with gravel. The man laying tile received 16 cts. per hr., and he averaged 640 ft. laid per 10-hr. day.

In New Jersey roadwork, where tile drains are used, the 4-in. tiles are frequently specified to be laid on a 1-in. yellow pine plank, 6 ins. wide, in a trench 2 ft. deep. If plank costs $20 per M delivered this item adds 1 ct. per lin. ft. The average bidding price in New Jersey has been about 12 cts. per lin. ft. for a 4-in. tile drain complete.

Vitrified Conduit Data.—Vitrified conduits for carrying electric wires underground are made in single or multiple ducts. A single duct is a pipe 18 ins. long with a round or square bore ranging from 3¼ to 4 ins. diameter. Multiple ducts are made with two or more ducts in one piece. The common multiples are 2, 3, 4, 6 or 9 ducts in one piece. The lengths of the pieces are 24 or 36 ins. Ducts are sold by the duct-foot, and the present price in New York City is about 3½ cts. per duct-foot. A six-duct multiple has 6 duct-feet per lin. ft., and its price is therefore 6 × 3½, or 21 cts. per lin. ft. of the 6-duct piece. The weight varies somewhat with different manufacturers, but 8 lbs. per duct foot may be used for estimating freight and haulage.

I am informed by one of the large manufacturers that

the 9-duct multiple is not so popular as it once was, due to loss by breakage.

The outside dimensions of vitrified conduits are about as follows:

Number of ducts in the piece	1	2	3	4	6	9
Dimensions of the piece, ins.......	5x5	5x9	5x13	9x9	9x13	13x18

These ducts are all square bore, 3¼ ins., square with rounded corners.

Cost of Laying Electric Conduits.—My own cost records for this class of work cover only two sizes of vitrified pipe conduits encased in concrete. One of these conduits was made of four-duct pipe, each duct being 3½ ins. inside diameter, the four ducts being baked together in one piece 18 ins. long. First a trench was dug 2 ft. 8 ins. deep and 18 ins. wide, then a bed of concrete 4 ins. thick was laid in the trench. Upon this concrete the conduit was laid, every joint being wrapped with a strip of cheap cotton cloth. Then concrete was packed on both sides of the conduit and 4 ins. thick over its top. The labor cost of laying this conduit, not including the cost of trenching and the cost of making and placing the concrete, was as follows: Two men laying the duct pipe and one helper delivering pipe from piles along the sidewalk, averaged 60 lin. ft. of 4-duct conduit laid per hour, which is equivalent to 120 ft. of single duct per hour. With wages of duct layers at 20 cts. each per hour, and helper at 15 cts. per hour the cost of laying was a trifle less than 1 ct. per lin. ft. of 4-duct conduit, or ¼ ct. per ft. of single duct.

In laying a 9-duct conduit (each piece of pipe having 9 ducts instead of 4 as above), two men laying were supplied with pipe by two helpers. This gang averaged 30 lin. ft. of 9-duct conduit per hour, at a cost of 2.3 cts. per lin. ft. of conduit, or ¼ ct. per ft. of single duct. From this it appears that the labor cost of laying the pipe is practically the same per duct-foot, whether 4-duct or 9-duct conduit is laid.

At another time, one man laying a single duct line (exclusive of trenching and concreting) averaged 66 lin. ft. per hour, at a cost of a trifle less than ¼ ct. per ft. The work in all these cases was done by day labor for the company.

Cost of Brick Manholes for Electric Conduits.—Square manholes were built with brick walls 12 ins. thick. The bottom of the manhole was concrete, and the top was reinforced concrete. The following data relate only to the brick work: Each manhole contained 4.6 cu. yds. of brick masonry, and the following gang averaged 1¾ days to each manhole, the day being 8 hrs. long:

2 masons, at $3.00	$6.00
3 helpers, at $1.50	4.50
Total per day	$10.50

Therefore, it cost $18.35 per manhole for the labor on the brick work, which is equivalent to $4 per cu. yd. of brick masonry. Since each manhole contained 2,140 bricks, each mason averaged about 600 bricks laid per 8-hr. day. This was very slow work. It was done by day labor for a company.

Cost of Vitrified Conduits, Memphis, Tenn.—Mr. F. G. Proutt gives the following data on electric vitrified conduit construction at Memphis, Tenn., in 1903: The work was done by day labor, the wages of common laborers (negroes) being $1.50 per day. There were about 3,700 ft. of trenches containing 27 ducts, and 7,200 ft. of trench containing 18 ducts, besides which there were 575 ft. of trench containing from 6 to 60 ducts, making in all 11,475 ft. of trench and 252,000 duct feet. An 18-duct conduit was made up of three 6-duct sections (no single duct sections were used), each section measuring 9 × 13 ins., sections being laid one on top of the other. The ducts were surrounded on all sides with concrete 3 ins. thick, making 6 ins. of concrete, 27 ins. of ducts and 30 ins. of backfill, or a trench 5¼ ft. deep for an 18-duct conduit. The width of the duct, 13 ins., plus 6 ins. for concrete, gives a trench 19 ins. wide, or about 8¼ cu. ft. (less than ⅓ cu. yd.) of excavation per foot of trench. The 27-duct conduit was made up of 4 multiple ducts of 6 ducts each, and one multiple of 3 ducts, laid in tiers, making the trench 6¼ ft. deep and 19 ins. wide, or about 9.4 cu. ft. per foot of trench. Roughly speak-

ing, all the trench work averaged ⅓ cu. yd. excavation per foot of trench. All 6-duct sections were 3 ft. long, and all 3-duct sections were 2 ft. long.

The executive force consisted of 1 general foreman at $3; 1 foreman of pipe layers; 1 foreman of concrete mixing gang; 1 foreman in charge of digging for manholes; 1 foreman in charge of backfilling and hauling away, and 1 time keeper. There were 8 men on manholes and service boxes, 80 men trenching, concreting and pipe laying. The best day's work was 703 ft. of trench and 15,156 duct feet.

In laying the ducts, the 3-in. concrete bottom was first placed, then 2 men in the trench laid the lower tier or run, two men on the bank handing the sections down by means of a rope run through one of the holes. This run was followed by a similar gang of 4 men working a few lengths back. Three dowel pins were used in each section. The joint was made with a strip of cheap canvas 5 ins. wide by 5 ft. long laid on the bottom before placing the ducts. A boy followed along, wrapping the canvas over the top joint and painting the lap with asphaltum. To cut the canvas into strips a table was made with a saw kerf in it 5 ins. from one edge and at this edge was a strip against which to push the bolt of cloth. A large butcher knife was then run through the saw kerf and cloth, cutting off a strip 5 ins. wide and the length of the bolt. This strip was wound on a reel whose circumference was 5 ft., and a cut through the cloth at the circumference made strips 5 ft. long.

The concrete was mixed with "Dromedary" mixers costing about $200 each. A "Dromedary" mixer holds about ⅝ cu. yd. of concrete, and is hauled by two horses in tandem. Half the charge of sand is shoveled in, then the cement, then the rest of the sand, and finally the stone. The door is closed and the mixer hauled about 150 ft. to the water tank and from 6 to 8 pails of water are thrown in. If the concrete must be rehandled the mixer is hauled to a dumping board 6 ft. wide by 24 ft. long, made in two 6 × 12-ft. sections.

The cost of 252,000 duct feet, laid in 11,475 ft. of trench, was as follows:

254,500 duct feet (1% broken), at 5½ cts........	$13,997
45 cars of ducts unloaded, at $7.50..............	338
Labor trenching, backfilling, concreting and duct laying	7,745
Materials for 882 cu. yds. of 1:4:8 concrete,* at $5.22	4,604
32 brick manholes,† at $115	3,680
31 manhole drains,‡ at $86	2,666
48 service boxes,§ at $30	1,520
4,300 lin. yds. canvas (5 ft. wide), at 5 cts......	215
5 bbls. asphalt paint, at $30	150
40,000 dowel pins for ducts, at ½ ct............	200
Tools	800
City water	50
Plumbers repairing water pipes	100
New sidewalks	600
Repaving city streets	1,000
City inspection	195
Engineering	1,000
Incidentals	1,140
252,000 duct feet, at nearly 16 cts............	$40,000

*Each cubic yard of 1:4:8 concrete required 0.96 bbl. (a bbl. being counted as 4 cu. ft.) cement at $2.10 per bbl.; 0.56 cu. yd. of sand at $1.25 per cu. yd.; and 1.36 short tons of broken limestone at $2 a ton.

†Each manhole was 8-sided, 5 ft. wide by 7 ft. long and 6¾ ft. deep, inside measure, with 13-in. brick walls, a 6-in. concrete floor, and a 12-in. concrete top reinforced by old rails. There were 3,200 bricks in each manhole at $7.50 per M.; there were nearly 4 cu. yds. of concrete in the bottom and top at $5.75 per cu. yd. for materials. Masons were paid $6 a day and helpers $2. The cost of excavating for and building a manhole averaged about $40. The iron rails cost $5. The cast-iron cover for each manhole weighed 1,150 lbs. costing 1.9 cts. per lb.

‡Manhole drains averaged 170 ft. long of 6 in. sewer pipe, costing $10 for materials and $76 for labor.

§Service boxes contained 325 bricks each, and were 3 ft. square inside. with 9-in. walls, and provided with cast-iron covers like the manhole cover,

Cost of Making Cement Pipe.—Mr. Arthur S. Bent gives the following data: In 1892 four miles of 28-in. cement pipe were laid for an irrigation system in Riverside Co., California. The mortar was mixed by hand in boxes holding ½ cu. yd., and was hoed over 3 times dry and 3 times wet. It was then tamped (17-lb. tampers) by hand into sheet iron molds.

The pipe was 28 ins. diameter, 2½ ins. thick and in 2-

ft. lengths. The mixture used was 1 part Portland cement and 3½ parts pit gravel and sand. A gang of 25 men made 1 mile of pipe per week, or 35 ft. per man per day, or 1¾ cu. yds. of concrete per man per day. With wages at $1.75 a day the labor cost was $1 per cu. yd. of concrete in the pipe, or 5 cts. per lin. ft. of pipe. This pipe line, after seven years of use, showed no appreciable loss of water in its 4 miles of length.

The Miracle Pressed Stone Co., of Minneapolis, Minn., manufacture molds for making cement tile and cement sewer pipe with bell ends. Their catalogue contains the data given in the following table:

Cost of Cement Pipe, in 2-ft. Lengths.

(Mortar, 1 : 3 mixture; sand, 75 cts. per cu. yd.; cement, $2 per bbl.; labor, $2 per day.)

Kind of pipe.	Thickness.	Pipe, 2 ft. long. Cu. ft. of sand.	Cost of sand.	Cost of cement.	Cost of Labor.	Total cost, 2-ft. pipe.	Total cost per ft.
24″ Bell-End ...	2″	2.75	$0.075	$0.460	$0.15	$0.685	$0.34
24″ Straight. ..	2″	2.25	.063	.370	.12	.553	.28
20″ Bell-End ...	1¾″	1.95	.056	.325	.13	.511	.26
20″ Straight ...	1¾″	1.67	.045	.266	.09	.401	.20
18″ Bell-End ...	1¾″	1.84	.550	.230	.13	.445	.22
18″ Straight ...	1¾″	1.50	.450	.190	.10	.335	.17
15″ Bell-End ...	1⅝″	1.40	.039	.235	.11	.384	.19
15″ Straight ...	1⅝″	1.17	.033	.195	.08	.308	.15
12″ Bell-End ...	1½″	1.10	.030	.180	.10	.310	.16
12″ Straight ...	1½″	.88	.025	.145	.07	.240	.12
10″ Bell-End ...	1⅜″	.83	.250	.105	.10	.230	.12
10″ Straight ...	1⅜″	.68	.020	.850	.07	.175	.09

Cost of Concrete-Steel Sewers.—See Section VI., Concrete Construction, pages 365 to 382.

SECTION IX.

COST OF PILING, TRESTLING AND TIMBER WORK.

Piles.—*Foundation piles* are piles driven to support a bridge, building or other structure. They are usually spaced not closer than 3 ft. center to center.

Trestle piles are driven to form the posts of a trestle. There are usually 4 piles driven in a row; and these 4 piles, with their 12 × 12-in. cap and sway braces, are called a *bent*. In wagon road trestles 3 piles are enough for a bent. In falsework for bridge spans two piles to a bent will suffice for moderate spans, the bents being located just in advance of the panel points.

Batter piles are piles driven inclined; or driven plumb and afterward pulled over into an inclined position.

Sheet piles are piles driven touching one another so as to form a tight enclosure, as for a coffer-dam. Triple-lap sheet piles are often made by bolting or spiking three planks together, the middle plank being set off line from the outer planks, so as to form a rough tongue and groove. This is the Wakefield piling, the patent for which has recently expired. Interlocking sheet piles are made of steel, in a number of different forms.

Rings, or iron bands, are generally placed around the heads of wooden foundation or trestle piles to protect the head from "brooming" and splitting while being driven.

Shoes of cast or wrought iron were formerly used very often to protect the toes of piles driven in hard material; but shoes are rarely used nowadays.

Piles are sold by lumber dealers at 5 to 15 cts. per lin. ft. of pile for all ordinary lengths, but very long piles bring high prices per lin. ft. Specifications usually provide a contract price per lin. ft. for "piles delivered" on the work ready to drive; and another price per lin. ft. for "piles driven." The length of the "pile driven" is the full

length of the pile left in the work after cutting off the broomed head.

The actual cost of driving a pile should be recorded in dollars and cents per pile, as well as in cents per lin. ft. of pile driven; for costs vary less per pile than per lin. ft. This is evident when we consider that where the driving is easy a very long pile is driven in no longer time than is required for a short pile where driving is hard.

The author prefers to specify payment for "piles delivered" by the lineal foot, and for "piles driven," by the pile.

Pile Drivers.—There are three types of pile drivers: (1) Free-fall; (2) friction-clutch; and (3) steam-hammer. In the free-fall driver, the hammer is detached from the hoisting rope and allowed to fall freely upon the pile. In the friction-clutch driver, the hammer remains always attached to the hoisting rope, and, by means of a friction clutch on the hoisting engine, the drum is thrown into gear or out of gear at will. When the clutch is thrown out of gear, the hammer falls, dragging the hoisting rope after it. The Nasmyth steam-hammer is raised by steam acting direct upon a piston attached to the hammer. The hammer is raised about 3½ ft., and allowed to fall by gravity.

A steam hammer strikes about 60 blows per minute. A friction-clutch hammer strikes about 18 blows per minute when the hammer falls 12 ft.; and 25 blows per minute when the hammer falls only 5 ft. A free-fall hammer strikes about 7 blows per min. when the fall is 20 ft., and a hoisting engine is used.

The free-fall hammer is much used where horses do the hoisting instead of an engine. In either case a lug on top of the hammer is gripped by a pair of "tongs," which are tripped at the desired height, allowing the hammer to fall. The "tongs" descend slowly by gravity helped perhaps by the man who has tripped them, and they automatically grip the hammer again. The "tongs" are also called "scissors" or "nippers."

The two upright timbers that guide the hammer are called "leads," or "leaders," or "gins," or "ways." A common weight of hammer, for a free-fall or a friction-clutch machine is 2,000 to 3,000 lbs.

An "overhang driver" is a driver provided with leads that project 8 to 20 ft. beyond the base of support of the driver. The horizontal beams that support the leads of an overhang driver are trussed; and the weight of the engine on the rear of the trussed beams counterbalances the weight of the leads and the hammer on the front. A cheap driver of this type can readily be made for driving the bents of a pile trestle across a river, or other body of water, where a scow is not available for mounting the driver upon. The author has built such a driver with a 20-ft. overhang for driving falsework pile bents across a river.

A "railway pile driver" is a heavy driver of the "overhang" type, mounted on a railway flat car. Sometimes these drivers are made self-propelling; but frequently a locomotive is used in handling the driver. The leads are so made that they can be lowered when passing under overhead bridges, etc. In working with an overhang driver, there is always considerabe delay, for as soon as the 3 or 4 piles for a bent have been driven, they must be sawed off and capped with a 12 × 12-in. stick drift-bolted to the piles, before the beams or stringers can be laid to support the driver when it moves forward.

A "scow driver" will drive more piles per day than a "railway driver," because this delay in sawing off and capping each bent does not occur. Moreover, the piles are floated alongside the driver ready for instant use. The scow itself is quickly shifted by means of ropes from suitable anchorages to the winch-heads of the engine.

Excepting on railway work, land drivers (as distinguished from scow drivers) are seldom mounted on wheels running on a track; but are usually supported on rollers running on plank or timber runways laid down in advance of the driver. If the ground is very irregular, it must either be graded, or the timber runways for the driver must be supported by cribbing or blocking so as to give a level runway for the driver. The building of such a runway often retards the work of land-driving.

Excepting where the driving is exceedingly hard, the hammer is actually at work but a small fraction of the day at best. The contractor should, therefore, exercise his wits to reduce the lost time.

There are no very reliable data as to the relative effectiveness of the blows of steam-hammer drivers and friction-clutch drivers, but the following data by Mr. N. E. Weydert may prove of value:

In driving piles in Chicago, piles 54 ft. long were driven 52 ft., of which 27 ft. were in soft clay, and 25 ft. in tough clay. Each pile averaged 13 ins. in diameter. Using a Nasmyth steam hammer, striking 54 blows per minute, with a weight of 4,500 lbs. falling 3½ ft., it required 48 to 64 blows to drive the last foot when a follower 20 ft. long was used on top of the pile; but, without a follower, it is estimated it would have taken only 24 to 32 blows to drive the last foot. After a pile had stood 24 hrs. it required 300 to 600 blows of the hammer on the follower to drive it 1 ft.

In the same soil, using a 3,000-lb. drop hammer falling 30 ft., and striking a follower 20 ft. long, it required 16 blows to drive the last foot; but with the same hammer falling 15 ft., it required 32 to 36 blows on the follower to drive the pile the last foot.

The piles were tested with a load of 50 tons each for two weeks and showed no settlement.

The Steam Hammer vs. the Drop Hammer.*—Some 50 years ago, when the Nasmyth steam hammer came into prominence as a pile driver, it was predicted by engineers who had seen it that the days of the rope-hoisted hammer were numbered. Nor is it uncommon to read similar predictions even to this day. That the steam hammer weighing two tons and striking 60 blows a minute is a very effective machine no one can deny, but what appears to have been overlooked by many engineers is the fact that in nearly all driving of piles on land, a very small fraction of the working day of a pile-driving gang is spent in actual driving. This is particularly the case in building pile trestles with a railroad pile driver.

A record kept by the writer shows very clearly how little time is ordinarily spent in pile driving on trestle work, using the ordinary railroad pile driver with a friction-clutch engine. Each trestle bent consisted of four piles driven

*Abstracted from an editorial article written by the author for Engineering News, July 2, 1903, p. 13.

about 10 ft. into firm, dry earth, and bents were 15 ft. c. to c. It took about 20 blows of a 2,800-lb. hammer falling about 18 ft. to drive each pile, and, once the pile was in the leaders, these 20 blows were delivered in from 1 to 2 minutes, depending upon minor delays in keeping the pile plumb. The piles were not ringed. Hence we may say that in so far as the actual time of driving four piles was concerned, only 8 minutes were thus consumed per bent at the most. About 4 or 5 minutes were required to get each pile into the leaders, thus consuming some 20 minutes per bent.

Tabulating the time consumed in performing each detail we have:

	Minutes.
(1) Getting 4 piles into leaders	20
(2) Driving 4 piles	8
(3) Straightening and bracing the piles	27
(4) Leveling and nailing guide strips for sawing off	10
(5) Sawing off 4 piles	12
(6) Putting on cap and drift bolting it..........	13
(7) Pulling 3 stringers forward from last bent....	11
(8) Putting in 3 more stringers that overhang....	20
(9) Putting in 1 tie and spiking rail..............	4
Total time on one bent	125

Item (4) was unnecessarily long, due to the hair-splitting methods of the Y-level man, who was giving the cut-off. Even after the cleats to guide the saws were nailed on, he had them lowered ⅛-in.

Items (3) and (5) may frequently be reduced very materially, and always would be on contract work, but on work done for a railroad company, as this was, the end of the 10-hour day will find only 4 to 6 bents built under the conditions here given. If however, we assume a bent of four piles built in 100 minutes, we see that only 8 minutes of that time will be consumed in actual driving. In other words, only three-quarters of an hour out of the ten hours is spent in hammering the pile! This will doubtless be surprising to many engineers, and particularly to those who have been impressed by the speed of the Nasmyth steam hammers. Under a hustling, wide-awake con-

tractor, the writer has seen 10 bents driven and completed in a day with a friction-clutch driver; but even under such conditions the hammer was actually at work driving less than two hours.

It seems quite clear from the foregoing discussion, that maintenance-of-way engineers should look not to improvements in the form of hammer mechanism, but rather to improvements in the mechanism and methods of handling the piles, caps, stringers, etc. Very much can be accomplished in this respect by having a well-organized force with a clear-headed foreman at its head. In the example just cited the item of straightening piles was exceedingly expensive in time, in that it consumed nearly half an hour. This was largely due to the fact that the foreman did not appreciate the importance of sawing the pile heads square. He simply put the piles into the leaders with the heads rough sawed as they came from the forest. In one case the pile had a large prong of splintered wood projecting above the partly sawed head. Haste never makes more waste than in neglecting to square the pile heads, and guide the pile properly while driving it.

In this particular instance, since the driving was across dry land, the foreman should have secured a team with which to "snake" piles and timbers up alongside of or directly in front of the driver. Then the pile rope or "runner" could have been quickly hooked on to a chain already fastened around the pile or timber to be moved, with a saving of 50% in the time spent in getting material to place. It does not pay to make a team out of a pile driver and a gang of men.

Instead of spending 13 minutes getting a cap to place and drift-bolting it, not more than 6 or 7 minutes need have been so consumed. Two men can cross-cut a pile in 4 or 5 minutes, hence with eight men on four saws, item (5) can be reduced at least one-half. Running around looking for saws, mauls, drift bolts, etc., is one of the greatest causes of delay. For this reason there should be one or two men whose duty it is to bring tools and put them away immediately after they have served their purpose. The two leader men on the driver might well attend to the tools.

We see, by this method of timing, why the Nasmyth

steam hammer has failed to displace the friction-clutch hammer on trestle work, and we see that if any improvement is desirable in driver design it is not in the hammer mechanism, but rather in the means of mechanically handling the timbers. Finally we see that organization of the force is quite as essential as improvement in mechanism, while it possesses the decided advantage of costing nothing except what may be paid for a better quality of brain work.

From this discussion it should not be inferred that the steam hammer has no field of usefulness, for it has. Its field, however, is in scow or land driving, where a great number of foundation piles are to be driven close together, and especially where a great number of blows must be struck to secure the desired pile penetration.

Cost of Raymond Concrete Piles.—The Raymond concrete pile (patented 1896) is made as follows: A collapsible steel core, 30 ft. long, 20 ins. diam. at the top and 6 ins. at the bottom, is driven into the ground by an ordinary pile-driver. When it has reached the proper depth, a wedge is loosened, permitting the two sections of the core to come closer together, so that the core can be easily pulled out of the hole. In a sticky clay the hole would probably keep its shape until filled with concrete, but ordinarily the sides of the hole will collapse if not supported, so it is necessary to slip sleeves or shells of sheet iron over the core before driving it. These shells are left in the ground upon pulling the core, and they form a mold for the concrete. For a pile 25 ft. long, the shells are made in four lengths of No 20 iron that telescope, one over the other. They are slipped over the lower end of the core as it hangs in the pile-driver leads, and a rope is hitched around the outer sleeve. The engineman hoists the shells until they are all "un-telescoped" and hugging tight to the core, like joints of stove pipe on a mandrel. The rope is unfastened and the driving begins.

On the following work, the hammer weighed 3,100 lbs., and was operated by an ordinary friction clutch hoisting engine. The pile-driver had leads 50 ft. long, and was mounted on a turntable; the framework of the turntable in turn resting on rollers traveling on timbers laid on

the ground. The driver was moved along, and rotated when necessary, by ropes passing around the winch head of the engine. The hammer blow was received by an oak block fitting in a recess at the top of the steel core. This oak block was so battered by the blows that it had to be renewed about every 5 or 6 piles driven. A ¾-in. wire rope passing over a 10-in. sheave lasted for the driving of 130 piles, and then broke. With a larger sheave the life would have been much longer. My records show that when work was first begun, the crew averaged 10 piles per day of 10 hrs., but the average of the job in driving piles for the foundation of a building was 13 piles a day, the best day's work being 17 piles. The cost of labor and fuel per pile was as follows:

5 laborers on pile driver, at $1.75	$8.75
2 laborers handling the iron shells, at $1.75	3.50
1 engineman	3.00
6 laborers mixing and placing concrete	10.50
1 foreman	5.00
Coal and oil	2.50
Total, 13 piles, at $2.55	$33.25

This includes the placing of the concrete, which, if deducted, leaves less than $2 per pile for driving the core. A pile 25 ft. long, 6 ins. at the point and 18 ins. at the butt, contains 21¼ cu. ft. (nearly 0.8 cu. yd.), and has a surface area of 77 sq. ft. The weight of No. 20 iron (B. & S. gage) is 1.3 lbs. per sq. ft., making the weight of the iron shells approximately 100 lbs. per pile. The amount of cement in the concrete may be varied to suit the whim of the engineer or architect, from 1 bbl. to 2 bbls. per cu. yd. Probably 1¼ bbls. per cu. yd. is more than necessary. In the case under consideration the quantities and costs were as follows:

	Per pile.
1.2 bbls. cement (in 0.8 cu. yd.), at $1.75	$2.10
0.8 cu. yd. stone, at $1.25	1.00
⅓ cu. yd. sand, at $1.05	0.35
100 lbs. No. 20 iron (made into shells), at 3½ cts.	3.50
Labor (as above given)	2.55
Total, 25 ft. pile	$9.50

The contract price was $25 per pile, or $1 per lin. ft., and included, of course, cost of moving plant to and from the work, royalty on patent, etc.

To give an idea of the character of the soil and the time required for the various operations, the following will serve: Fall of hammer, 5 ft.; 32 blows per min.

10.15	a. m.	Start to drive pile core.
10.30	a. m.	Pile core down 23 ft.
10.39	a. m.	Start driving another pile.
10.46	a. m.	Stop to change oak block.
10.55	a. m.	Start driving again.
10.59	a. m.	Pile core down 24 ft.
11.03	a. m.	Pile core pulled out.
11.03½	a. m.	Pile driver moved ahead.
11.16	a. m.	Finished fixing deadman for pulling pile driver ahead.
11.23	a. m.	Steel shell on the core.
11.24½	a. m.	Pile core lined up and driving begun.
11.25	a. m.	16th blow, 6 ft. down.
11.27	a. m.	84th blow, 12 ft. down.
11.29½	a. m.	160th blow, stop to line up.
11.31½	a. m.	Start again.
11.32½	a. m.	190th blow, stop to line up.
11.33¼	a. m.	Start again.
11.33½	a. m.	196th blow, stop to line up.
11.34½	a. m.	Start again.
11.36½	a. m.	256th blow, 18 ft. down, and will go no further.

Cost of Making Piles.—Two men can cut down and trim 17 oak piles per day, each pile being 20 ft. long. Where the men are paid $1.75 per 10 hrs., the labor cost of making the piles is practically 1 ct. per lin. ft. To this must be added the cost of hauling and freight to the place where the piles are to be driven.

Cost of Driving Piles With a Horse Driver.—This work consisted in driving 219 piles, 2 ft. centers, to form the protecting toe of a slope-wall. The hammer weighed 2,000 lbs., and was raised with block and tackle by horses. Two teams were used alternately. As soon as the hammer was tripped, two men pulled back the hammer rope

hand over hand, and hooked it on to the second team while the other team was returning. In this way the blows were delivered almost twice as rapidly as when one team only is used. The driver was supported on wooden rollers sheathed with iron and provided with sockets into which bars could be inserted for turning the rollers. The rollers rested on planks laid on the ground which was comparatively level and required no staying or grading to secure a level runway for the driver. Pine piles, 15 ft. long, were driven in a stiff clay to a depth of 13 ft.

The average number of piles driven per 10-hr. day was 21, but the best day's record was 30. The cost was as follows per day:

5 laborers, at $1.50	$7.50
1 foreman, who worked	2.50
2 teams and drivers, at $3.00	6.00
Rent of driver	2.00
Total, for 21 piles, at 85 cts.	$18.00

The piles cost 10 cts. per ft. delivered; and the contract price was 24 cts. per ft. delivered and driven.

On another contract where piles were spaced 10 ft. centers, and driven 12 ft. into gravel along the sloping bank of a river, it was necessary to do more or less grading and blocking up to secure a level runway for the pile driver. Four men and a pair of horses averaged only 6 piles per 10-hr. day, making the cost about $1.50 per pile for the labor of driving. This gang was too small, and worked deliberately.

Cost of Driving Foundation Piles for a Building.— On this work, which consisted in driving long piles for the foundation of a building in Jersey City, a pile driver mounted on rollers was used. The leaders were 60 ft. long, and provided with two head sheaves, one for the hammer rope and one for the rope used in hauling and raising the piles. The hammer weighed 2,100 lbs.; and the engine was a double-drum friction-clutch. The piles were of spruce 50 ft. long, and were driven their full length in soft clay. For the first 10 ft. the piles were driven without ringing or banding. When the pile head reached the bottom of

the leaders, a short wooden follower was used for the last 10 to 25 blows. The pile ring was then pulled off the pile by a short iron pevee lifted by the pile rope. The piles were stacked up in the street about 100 ft. away from the driver, and were "snaked over," when wanted; the pile rope being used for the purpose. For the first few blows the hammer had a fall of only 5 ft., and about 25 blows per min. were delivered. But after that the fall of the hammer was 12 ft., and about 18 blows per min. were delivered. It required about 110 blows to drive a pile its full 50 ft. The time required to drive one pile was as follows:

	Minutes.
Hooking on dragging pile to driver	5
Hoisting pile and getting it in place	2
Hammering pile	6
Putting ring on pile	1
Placing follower on pile	½
Removing follower from pile	1
Removing ring from pile	½
Shifting pile driver 2 ft.	1
Total time per pile	17

It will be observed that the hammer was actually engaged in hammering not much more than one-third of the total time. When everything was working smoothly 35 piles were driven in 10 hrs., but the output frequently fell below 30 piles in a day, due to sundry slight delays and accidents.

The cost of operating the driver was as follows:

1 engineman	$3.00
1 man up the ladder	1.50
4 men handling and guiding pile	6.00
1 man sharpening piles	1.50
1 foreman handling pile rope, etc.	4.00
⅓ ton coal, at $6	2.00
Total per day for labor and fuel	$18.00
Rent of pile driver	3.00
Total, at 60 to 70 cts. per pile	$21.00

Cost of Driving Piles for Wagon Road Trestles.—It was necessary to drive piles for a number of wagon road trestles across ravines, which were often separated by several miles. A light pile driver that could readily be moved from place to place was built. This pile driver contained all told about 600 ft. B. M. of timber. The hammer weighed 1,200 lbs. and was raised by a 1-in. rope passing over a pulley at the top of the leaders and down around a wooden drum 12 ins. in diameter. This drum was provided with a wooden bull-wheel, built of 2-in. plank, and was 5 ft. in diameter. A rope around this bull-wheel was pulled by a single horse in raising the hammer. This design was simpler, cheaper and more effective than using triple blocks and tackle. The leaders of the pile driver were of 4 × 6-in. pine, 30 ft. long. The ladder was of 2 × 4-in. pine. The side braces were of 4 × 4-in. stuff, and the bed frame of 6 × 6-in. stuff. This driver, including the 5-ft. bull-wheel and the 1-ft. drum, was built by 4 men in two days, at a cost of $16 for labor, and $8 for timber and bolts.

Piles were driven in bents of three piles each, bents 20 ft. apart. In fairly hard ground the piles were driven only 5 or 6 ft. deep. Due to the irregularity of the ground, it was generally necessary to throw up a rough staging to support the driver while driving. The crew consisted of 4 men and 1 horse. It would take them about 2 days to move the driver 4 miles over poor roads, and erect a staging upon which to drive a seven-bent trestle. Then they would average 10 piles driven per 10-hr. day. The cost of actual driving was about $1 per pile, wages being $10 a day for the crew; to which must be added another $1 per pile for lost time moving driver from one trestle to the next and building staging.

Cedar piles were largely used for this work, as the driving was light, and as the durability of cedar is greater than other woods. After driving the piles, 2 men would saw off the heads of 18 piles in 3 hrs., at 6 cts. per pile. These piles averaged 20 ft. in length, and with axmen at $2 a day each, they were cut down and trimmed for 25 cts. a pile, and hauled 3 miles over rough roads for 50 cts. more per pile.

I found it economic to sublet the pile driving to a reliable carpenter who would work with his gang of three men, and earn good wages for himself and crew if paid $2 for driving each pile, including all moving and building of staging. The work just described was done in this way. Work handled thus generally insures activity on the part of small gangs of men and reduces the charges for superintendence to a very small percentage.

Cost of Driving Piles for a Trestle, N. P. Ry.—Mr. E. H. Beckler gives the following data on driving piles for a railway trestle and three truss bridges on the N. P. Ry., at Duluth, Minn., by contract in 1884. The work was all done in the winter, and about 2,340 piles were driven, of which 460 were in foundations. The trestle was 5,000 ft. long. A pile driver, having leaders 65 ft. long, and a 2,600-lb. hammer, was used. The piles were of Norway and white pine, the average length being 51 ft. From 50 to 150 blows were struck on each pile. With a 20-ft. fall the hammer struck 7 blows per min. The penetration was 10 to 42 ft. The average cut-off was 5 ft. for the trestle piles. The pile driver engine was mounted on the driver platform to give stability and for ease of moving. A 900-lb. follower was used in driving some of the piles, but it was found to reduce the peretration of each blow about 20%, and it did not save the heads of the piles from more or less shattering.

Some piles were driven butt down, but it added 25% to the cost of driving; and it was believed that the small end, being exposed, would decay faster than the butt end. Moreover, the area of the small end was so small that the pile would not stand heavy driving without shattering.

The cost of operating one pile driver was about $38 a day and from Dec. 11 to Mar. 5 the record of its work was as follows:

	Per pile.
202 piles (32 ft. long), 19.2 piles per day..........	$2.25
134 piles (44 ft. long), 23.3 piles per day..........	1.65
364 piles (60 ft. long), 25.1 piles per day..........	1.50
379 piles (66 ft. long), 19.2 piles per day..........	1.95
73 piles (65 ft. long), 22.5 piles per day..........	1.85

These costs represent the cost to the contractor.

As many as 30 piles a day for 4 consecutive days were driven. The average cost of driving these 1,152 piles, it will be seen, was nearly $1.75 per pile.

The driving was done after the ice had formed in the bay, and the pile driver was supported by the ice during driving.

The soil was 7 ft. of clay under which was sand. Before the work was begun, test piles were driven from a scow along the line of the trestle 300 ft. apart. This enabled the engineers to make out an accurate bill of pile timber for the work.

It was found that Norway pine piles stood the driving in cold weather (as low as —15° F.) much better than white pine; for, when wood freezes, it is brittle.

The test piles were nearly all broken off several feet below the ground level, by the side thrust of the ice that formed to a thickness of 4 ft. after the piles were driven. Three test piles were pulled up by the ice, although they had been driven 40 ft. into mud. The combined strength of four piles in a bent was required to resist the lateral thrust of ice pushed by the wind. The ice was unable to lift the piles once the trestle was finished.

Cost of Pile Driving, O. & St. L. Ry.—Mr. A. E. Buchannan gives the following data of work done, Oct. 22 to Dec. 17, 1889, on the Omaha & St. Louis Ry., by company labor. There were 46 days worked, the actual working time being 6 hrs. 52 mins. per day. The railway driver drove 1,267 piles in these 316 hrs. of which time 14 hrs. were lost in lowering the leads 344 times, or 2½ mins. each time. The average time to drive a pile, it will be seen, was 15 mins. The average depth driven was 14 ft. The work was on 41 different trestles, each averaging 101 ft. long. Wages were $2.40 for engineman, $2.00 for fireman, and $1.50 to $1.75 for laborers. The cost of the 46 days' work was:

Wages	$1,684
Fuel, etc.	262
Total, 1,267 piles, at $1.54	$1,946

The poorest day's work was 11 piles; the best, 44 piles; the average, 28 piles.

Cost of Pile Driving, C. & E. I. Ry.—Mr. A. S. Markley gives the following data relative to the cost of driving 436 piles on 16 jobs, averaging 27 piles on each job. The work was done in 1902 for the C. & E. I. Ry., using a self-propelling railway pile driver made by the Industrial Works, Bay City, Mich. No locomotive was required as the driver could run at a speed of 10 miles an hour and pull 5 cars on a level road. The leads were 47 ft. long; the hammer, 2,900 lbs.; the hoisting rope, 2-in.; and the engine 30-HP., double cylinder. The leads could be raised in 2 mins. The engineman received $2.50 a day; the fireman, $1.50; the rest of the men were laborers, except the foreman. The average cost of driving each pile was 75 cts.; and each pile averaged 24 ft. long, although the range was from 14 to 42 ft.

The Record for Rapid Driving on the O. & M. R. R.—As illustrating what can be done under favorable conditions where men are rushing their work, a record given by Mr. L. C. Fitch, Engineer of Maintenance-of-Way, Ohio & Miss. R. R., is interesting. A pile driver crew drove 28 piles (7 bents of 4 piles each) in 3 hrs., at a cost of 30 cts. per pile. The piles averaged 21 ft. long and were driven 15 ft. into the ground.

Cost of a Pile Trestle.—Mr. Henry H. Carter gives the following costs of building a trestle across a pond in Massachusetts. The work was done by contract, occupying five months, beginning November, 1883, and ending April 9, 1884. The piles were driven in bents of 8 piles to the bent, bents 4 ft. apart, and capped with 10 × 10's 35 ft. long, notched down (dapped) 2 ins. on each pile. On the caps were laid four lines of 8 × 10-in. stringers, and on these were laid the ties for a double track road for contractor's dump cars. This trestle was filled with gravel, and afterward all but the two outer piles in each bent were cut off 7 ft. below water and used as a foundation for a masonry conduit. The average length of the 3,750 piles driven was 37 ft., about 25% of the piles being over 45 ft. long. With the hammer falling about 12 ft., 318 of the piles penetrated less than 1 in. under the last blow (very hard driving); 950 piles pene-

trated 1.3 to 2.7 ins. under the last blow (hard driving); 2,016 piles penetrated 3 to 4 ins. under the last blow (medium driving); and 141 piles penetrated over 4 ins. under the last blow (easy driving). In general the piles were driven through several feet of very soft mud and 12 ft. into the hard bottom. The piles were driven by two floating pile drivers supported on a raft made of timbers and empty oil barrels. The cost of the work was as follows:

Making pile driver:

Foreman, 7 days, at $3.25	$22.75
Engineman, 7 days, at $3.25	22.75
Laborers, 15 days at $1.75	26.25
Carpenter, 14 days, at $2.25	31.50
Carpenter, 18 days, at $2.00	36.00
Gins	124.00
Floats	314.95
Total	$578.20

The cost of building this driver if distributed over the 3,638 piles driven, amounts to nearly 16 cts. per pile. The other costs were as follows:

Loading and transporting piles:

Foreman, 96¼ days, at $2.00	$192.50
Laborers, 449 days, at $1.75	785.75
Horse, 104¾ days, at $1.50	157.12
Sleds	3.50

Pile driving:

Foreman, 82 days, at $3.25	266.50
Foreman, 118½ days, at $3.00	355.50
Foreman, 95 days, at $2.50	237.50
Engineman, 87 days, at $3.25	287.75
Engineman, 103½ days, at $2.50	258.75
Topman, 166 days, at $2.00	332.00
Topman, 17 days, at $1.75	29.75
Deckhand, 116½ days, at $2.25	262.12
Deckhand, 255¼ days, at $2.00	510.50
Deckhand, 280 days, at $1.75	490.00
Laborer, 20 days, at $1.00	20.00

Carpenter, 177 days, at $2.25	$398.25
Carpenter, 172 days, at $2.00	344.00
Freight on pile drivers	75.00
Coal, 35 tons, at $6.40	224.00
Interest on plant, 180 days, at $1.50	270.00
11 M spruce braces, at $14	154.00
872 lbs. spikes in braces, at 3 cts.	26.16
Tools	120.00
Piles:	
3,638 spruce piles (av. 37 ft. each), at $2.26	8,221.88
	$14,022.53

The loading and transporting of the 3,638 piles cost $0.32 per pile. The driving cost $1.30 per pile, the average number of piles driven being 20 per day. The cost of each pile averaged $2.26. The total cost of each pile driven was $4.04 including cost of making scow, interest on driver, labor, fuel and cost of pile. The interest on the driver, $1.50 a day, is too low an estimate under ordinary conditions.

The cost of the materials and labor for caps, stringers and ties (there were no sway braces) was as follows:

Transporting timber:

Foreman, 19 days, at $2.00	$38.00
Laborer, 89 days, at $1.75	155.75
Laborer, 4 days, at $1.50	6.00
Horse, 20 days, at $1.50	30.00
Sled	1.50
Total	$231.25

Labor on caps and stringers:

Foreman, 16 days, at $3.25	$52.00
Foreman, 20 days, at $2.50	50.00
Carpenter, 60 days, at $2.25	135.00
Carpenter, 58 days, at $2.00	116.00

Caps and stringers:

159 M spruce, at $16.10	$2,559.90
12 M spruce bolsters, at $13.50	162.00
3.6 M spruce plank, at $14.00	50.40

10,490 lbs. bolts, at 2⅝ cts.	$283.23
3,830 lbs. bolts, at 3 cts	114.90
88 lbs. spikes, at 3 cts.	2.64
Building derricks	5.00
Tools	28.50
Total for caps and stringers	$3,559.57

The cost of transporting timbers to the trestle ($231.25) applies not only to the 175 M of caps and stringers, but also to 24 M of ties and 27 M of sheet piling and wales, making the cost of transporting practically $1 per M. The other labor involved in placing the caps and stringers ($353) after delivery, is equivalent to $2 per M, making a total of $3 per M for the labor on the caps and stringers. The cost of placing the ties was as follows:

Placing ties:	
Laborer, 4½ days, at $1.00	$4.50
Laborer, 6 days, at $1.50	9.00
Laborer, 51¾ days, at $2.00	103.50
Ties:	
24.18 M spruce ties, at $14	338.52
540 lbs. spikes, at 3 cts	16.20
Total	$471.72

From this it appears that the cost of placing ties was nearly $5 per M (or 21.3 cts. per tie) to which must be added $1 per M for loading and transporting.

The cost of sheet piling was as follows:

Sheet piling:	
25.5 M sheet piling, at $18.60	$474.30
1.2 M spruce wales, at $16.00	19.20
205 lbs. spikes, at 3 cts.	6.15
Interest on pile driver, 16 days, at $1.40	22.40
3 tons coal, at $6.40	19.20
Foreman, 16 days, at $3.25	52.00
Engineman, 16 days, at $3.25	52.00
Topman, 16 days, at $2.00	32.00
Deckhand, 16 days, at $2.00	32.00

Deckhand, 40¾ days, at $1.75	$71.31
Carpenter, 32 days, at $2.00	64.00
Total	$844.56

The cost of driving the 25.5 M and placing the 1.2 M was nearly $13 per M. This sheet piling was 4-in. tongued and grooved, driven for two culverts.

The cost of sawing, dapping (notched 2 ins.) and fitting 280 caps for 280 pile bents of 6 piles to the bent was as follows: Cost to saw off piles, and fit caps, $2.95 per cap, or $2 per M (for each cap was 10 × 10 ins. × 18 ft.). The piles were sawed off at the bottom of a wet trench, and it cost 90 cts. per bent to saw away the earth. Carpenters received $2.50, laborers $1.25, and foreman $3.50 a day. The gang consisted of 1 foreman, 3 laborers and 4 carpenters.

These caps were covered with a platform of 4-in. spruce plank run lengthwise of the trench, laid to break joint, and spiked to the caps with 8-in. cut spikes. This platform was laid with a force of 1 foreman, at $3.50; 8 laborers, at $1.50, and 1 carpenter, at $2.50. The cost of laying 900 M was $7.40 per M. The contractor doing this work failed.

Cost of a Pile Docking.—This work consisted in driving a row of oak piles, 25 ft. long and 5 ft. centers, to an average depth of 10 ft. into gravel. The piles were sheeted on the rear with 3-in. oak plank laid horizontally and breaking joints. A waling piece, of 10 × 12-in. oak, was bolted along the front face of this docking, and anchored back to stone deadmen. The anchor rods were 1¾-in., spaced 10 ft. apart. Back of this docking an earth fill was placed, but the following costs relate only to the timber work. A pile driver, mounted on rollers, and operated by a friction-clutch engine, was used. The daily cost of operation was as follows:

7 men, at $1.50	$10.50
1 foreman	3.00
1 pair of horses	1.50
Rent of driver and engine	3.00
¼ ton coal, at $4	1.00
Total, 10 piles driven, at $1.90	$19.00

The piles were of oak and two of the men peeled and pointed them and square-sawed the heads. The horses were used to drag the piles up to the driver. There was some grading and scaffolding work necessary to provide a level runway for the driver. The foreman was not a good manager, and the cost was much higher than it should have been. On one day when the work was pushed and when conditions were favorable, 25 piles were driven.

The labor cost of placing the sheet planking and wale piece was $4.50 per M, about 80% of the timber being the 3-in. planking. This work was done by common laborers working in pairs, at $1.50 each per 10-hr. day. The piles were not always plumb and seldom spaced exactly, so that a measuring pole had to be used to fit each plank, and every plank had to be sawed separately by the men. Had the engineer so designed the work that the planks could have been set on end, like sheet piling, all this fitting and sawing of individual planks could have been avoided, with consequent reduction in the cost. Moreover there would have been less wastage of plank. Such a design would have necessitated two more small-sized wale pieces, but it would have made easy the removal of any single plank at any time for repairs due to rotting. In boring the oak wale pieces and piles with a 1¾-in. ship auger, a man would bore 12 ins. in 5 mins. It took 5 mins. for two men to cut off a 10 × 12-in. oak stick using a cross-cut saw.

It may be well to note that the plans called for the driving of 3 × 8-in. oak sheet piling to a depth of 5 ft. by hand, using wooden mauls. It was found impossible to drive these planks more than 2 ft. into the gravel without battering the heads to pieces.

Data on Driving Plumb and Batter Piles, New York Docks.—Mr. Charles W. Raymond gives the following data on the driving of piles for docks, Hudson River, New York City, prior to 1880: Piles were driven with a scow pile driver, the scow being 3 × 20 × 42 ft., provided with leaders 50 ft. long. The engine was a 10-HP. friction-clutch hoisting engine, with double cylinders, 6 × 12 ins. The boiler was 15 HP., upright. A crew of 8 men worked 8 hrs. per day for the city, and drove 10 to 15 piles per day. The piles averaged about 65 ft. long, and were driven

55 to 60 ft. below mean low water, penetrating about 10 ft. of gravel and cobbles (6-in. and less) that were filled in over the dredged area before driving. Then the piles penetrated about 25 ft. of river muck, making a total penetration of 35 ft. There was no difficulty in driving through the cobbles and gravel without brooming the piles. All piles were sharpened, and their heads were squared. To indicate the kind of driving, two records of 50 piles show that 230 blows of the hammer were required to secure a penetration of 38 ft., or 180 blows to secure a penetration of 33 ft. The last foot of penetration required 13 to 14 blows of a 3,000-lb. hammer falling 8 ft. (not freely, but with the hammer rope).

A special driver, with leaders inclined 1 to 6, was used to drive batter piles, and the average number of piles driven per day was about half as many as in driving plumb piles, or 5 to 7 piles per 8-hr. day. The number of blows per batter pile was somewhat greater than per plumb pile, but by no means enough greater to account for the slower driving, which was probably due to difficulty in getting the batter pile properly started.

Data on Driving Piles for Docks, New York.—Mr. Eugene Lentilhon states that in 1896 the following comparative records were made with a drop hammer and a Vulcan steam hammer: The driving was for a dock on the Hudson River, New York City, and was very hard driving, the material being 10 ft. of cobbles underlaid by sand and gravel. The piles were spaced 3 ft. apart, and driven from scows. The drop-hammer, friction-clutch machine had a crew of 10 men. It required 175 blows of a 3,300-lb. hammer falling 10 ft. to drive a pile; and 15 blows were struck per minute, hence the actual time of hammering a pile was about 12 mins. The piles were 55 to 60 ft. long and penetrated 21 to 28 ft. The crew averaged 12 piles per 10-hr. day.

As compared with this a crew of 8 men, using a Vulcan steam hammer, averaged 18 piles per 10 hrs. The machine weighed 8,400 lbs., and the striking piston weighed 4,000 lbs. and had a drop of 3½ ft. It struck 60 blows per minute, and some piles required as many as 1,200 blows. Mr. Lentilhon does not make it clear why the steam hammer

was more effective than the drop hammer. It is probable, however, that there were fewer delays in straightening up the pile during driving when a steam hammer was used. He states that there were two objections to the steam hammer, one of which was the frequent loss of the "cap" or "saucepan," or "hood," by dropping into the water, and the rapidity with which the "cap" was worn out. Only 38 piles were driven with each cap before it was worn out. The second objection was the impracticability of driving crooked piles.

Cost of Driving and Sawing Off Piles.—Mr. Eugene Lentilhon, in Trans. Am. Soc. C. E., Vol. 31 (1894), p. 569, describes the construction of a concrete sewer on a pile foundation, built by the New York City Dock Dept. The piles were driven by a scow driver with a 3,400-lb. hammer, which worked 65 days. Wages were $2.30 for laborers, $3.50 for engineman, and $3.00 for dock-builders, per 10 hrs. The average was 8 piles driven per day, at a cost of $3.90 for labor of driving. The piles were sawed off 1 ft. below mean low water. The dock builders fastened small battens on opposite sides of a pile to guide the saw, and frequently two men during a good low tide sawed off 3 piles. The cost of sawing off was $1.28 per pile.

Data on Driving With a Steam Hammer and Sawing Off Piles.—Mr. Sanford E. Thomson gives the following data on driving and sawing off piles for the Cambridge Bridge, at Boston, in 1901. A Warrington steam hammer, made by the Vulcan Iron Works, of Chicago, was used by the contractors. It weighed 9,800 lbs., and the striking part weighed 5,000 lbs. With 90 to 100 lbs. of steam, the hammer would strike 60 to 70 blows per minute, falling by gravity. The top of the leaders of the scow driver was 75 ft. above the water surface. After a pile was well down, an oak follower, 14 ins, square and 30 ft. long, was placed on the pile to complete the driving, so that the pile head was left 18 ft. below the water surface. The average 10-hrs. work of a driver was 100 piles, but on one day as many as 212 piles were driven in 9 hrs. The piles were 40 ft. long and driven in hard clay.

The piles were cut off 15 to 34 ft. below low water by a rotary saw mounted on another scow. A 40-HP. engine

running at 150 revolutions per minute was geared up to the saw shaft so as to drive the saw at about 450 revolutions per minute. A 42-in. saw was mounted at the lower end of a hollow vertical shaft 4 ins. in diameter and 60 ft. long. This shaft was supported by three pillow-block bearings which were bolted to a spud 14 ins. square and 60 ft. long; so that when the spud was raised or lowered the saw shaft moved with it. The pulley on the saw shaft was arranged to slide on a spline or key, so that the shaft could be raised without raising the pulley. The belt from the pulley ran to another pulley mounted on a short vertical jack-shaft, provided with a bevel gear wheel meshing with another bevel gear wheel on a horizontal shaft driven by the engine. This horizontal shaft was geared to the engine with a link belt. This machine sawed off 600 to 800 piles per 10-hr. day. The spruce piles were 10 ins. diameter.

Cost of Driving Piles for a Swing Bridge.—A steel highway swing bridge, 240 ft. long, and 16-ft. roadway, was to be supported on a pier in the center of the river. The piles were Washington fir, driven to an average depth of 20 ft. in gravel. The penetration under the last blow of a 2,400-lb. hammer, falling freely 27 ft., was 3 to 4 ins. A scow pile driver was used, and the force to operate it was as follows:

	Per day.
1 engineman	$3.00
1 man tripping hammer	1.75
2 men guiding pile	3.50
2 men making ready the next pile	3.50
½ foreman	2.50
⅓ ton coal, at $9	3.00
Total per 10 hrs.	$15.25
Rent of driver	6.00
Total	$21.25

This force averaged 26 piles per 10-hr. day. The foreman supervised another gang of men, so that half his wages were charged to this work. The piles were neither

peeled nor sharpened, for I found no economy in so doing. There were 42 piles in the pier, and twice as many more in the pier protection bents upstream and downstream, which also served as falsework upon which to build the bridge. The piles in these bents were sawed off, capped and sheeted with plank. Two men with a cross-cut saw would saw off 30 of the piles in the bents in 10 hrs., at about 12 cts. per pile. The cost of sawing off the piles below water for the pier is given in the next paragraph.

Cost of Sawing Off 42 Piles Under Water.—It was necessary to cut off 42 piles, 4 ft. below extreme low water for the pier work just described. A gravel bar occupied the site of the pier, and, although the water was about 4 ft. deep over the bar at the time of pile driving, it was necessary to dredge this bar at least 4 ft. deeper. A hole 4 ft. deep, and 27 ft. square on a side, was dredged with an ordinary drag scraper equipped with long handles and hauled by the pile-driver engine. The men operating the scraper walked on a raft. It took 3½ days of the pile driver crew, above given, to do this dredging, at $21 per day, or $74. The 42 piles were driven in this hole, after driving 4 piles above the hole and sheeting them with plank to act as a temporary sheer dam to prevent the river current (3 miles per hr.) from filling in the hole with gravel during pile driving. The 42 piles were cut off about 8 ft. under water with a circular saw mounted on a shaft driven by the pile-driver engine. A saw, shaft, pulleys and belt were bought for this purpose and rigged up by the pile-driver crew. It took them 3 days to rig the saw and cut off the 42 piles. The hole had not been dredged deep enough and the gravel that had washed in dulled the teeth of the saw requiring frequent raising to resharpen it. Moreover, the engine did not have sufficient power to drive the saw at high speed, and the piles were as much chewed off as sawed off. All these, however, are conditions apt to be met in similar work on small jobs. The 3 days' sawing cost $64, or $1.50 per pile.

Data on Sawing Off Burlington Bridge Pier Piles.—Mr. C. Hudson gives the following description of the method used in sawing off several hundred piles for the Burlington Bridge pier, in 1868:

The piles when driven, were sawed off by machinery. On each side of the pier, and a few feet away from it, a row of piles, perhaps 6 or 8 ft. apart, was driven. These were capped, and upon the cap was placed a traveler 12 ft. wide, arranged to be moved from end to end of the pier on these caps. Upon this traveler was another and smaller one, arranged to run upon it and across the pier. This last traveler carried a vertical shaft in a properly braced frame. This shaft carried at its lower end a circular saw about 36 ins. in diameter. The shaft could be raised or lowered as required, and was driven by means of a beveled gear from a horizontal shaft on the little traveler. A long belt extended the whole length of the large traveler, around a pulley on this horizontal shaft and another guide pulley, so arranged that the shaft was turned regardless of the position of the little traveler. An engine on a boat alongside the pier was the motive power.

The little traveler was fed across the pier by means of a set of small blocks on each side, and a line which ran around a wheel shaft like a ship's steering wheel. By this means the traveler could be moved either way, and could thus cut off a row of piles running one way, and then, by feeding back cut the next row, the large traveler having been moved back to reach it. In this way 12 or 15 piles were cut off per hour. The efficiency of the saw under water is, of course, very much less than in the air.

Cost of Pulling Piles.—In Engineering News, April 16, 1903, were described and illustrated two types of machines that I have used for pulling piles from the bed of a river. Several hundred piles were pulled with a tripod machine, with gear wheels and triple blocks that multiplied the power 270 times. A rope passed from the drum of the machine to a 4-HP. hoisting engine, which was thus able to pull piles driven 27 ft. into the ground. It cost $100 to make two of these machines and about $300 more for blocks and tackle and repairs.

The crew for each puller was 3 laborers, 1 boss and 1 engineman, so that the cost of wages and ¼ ton of coal was $10 per day. About 700 piles were pulled with two machines, the average depth of pile being 12 ft., although many were 25 ft. The average day's work per machine

was 15 piles making the cost of labor and fuel about 70 cts. per pile. The men worked in water up to their knees and were provided with rubber boots costing $100, which, with the $400 paid for machines and repairs, made $500, or about 70 cts. more per pile.

Chains that were wrapped around the piles in pulling were made of 1¼-in. iron, with a breaking strength of about 100,000 lbs. The strain was so great in pulling the longest piles that the chains were frequently broken.

Cost of Blasting Piles.—Several hundred piles were removed by blasting, in addition to the 700 that were pulled as above described. The piles had been cut off at the water's surface many years before, and our contract required the removal of the piles at least 4 ft. below the surface of the low water, which was equivalent to about 2 ft. below the bed of the river. Long ship augers were used to bore holes 1½ ins. in diameter and 4½ ft. deep, down the core each pile. Each laborer averaged 7 such holes bored per 10 hrs. in white oak piles. The cost per pile for boring and blasting was:

Labor boring, 15 cts. per hr.	$0.21
1 lb. of 70% dynamite	0.20
½ lb. of 40% dynamite	0.08
5 ft. of fuse	0.03
1 cap	0.01
Total per pile	$0.53

Each pile was loaded with two sticks of 70% dynamite and one stick of 40%. This charge would cut off the largest pile and hurl the butt 75 ft. in the air. Occasionally a very tough pile would be splintered, and had to be pulled. This added cost of pulling averaged 10 cts. more per pile, which might have been avoided by making all three sticks 70% dynamite.

Cost of Pulling and Driving Piles for a Guard Pier.—The pile protection, or guard pier, of an old draw bridge, across a tributary of the Hudson River, was removed and new piles were driven. The author sublet the work, and the following are the actual costs to the subcontractor:

The number of piles pulled was 200, and the time re-

quired was 10 days. A scow pile driver was used, the engine being a friction-clutch machine, and the hammer weighing 2,200 lbs. To pull the piles, a pair of heavy triple-sheave blocks were used. The pulling was easy, the piles being only 10 to 15 ft. in rather soft ground. The daily (10-hr.) cost of operating the scow was as follows:

	Per day.
1 captain of driver	$2.50
1 engineman	2.00
3 men, at $1.80	5.40
⅓ ton coal, at $3	1.00
Rent of driver	5.00
Total, 20 piles pulled, at 80 cts.	$15.90

This same crew then drove 200 new piles in 20 days, or 10 piles per day, at a cost of $1.60 per pile. The piles were driven 15 to 20 ft., and were 30 to 35 ft. long after cutting off. The slowness of the driving was largely due to delays caused by navigation at high tide, the channel being so narrow that the driver had to drop down with the tide to make way for boats to pass, and then pull back against the tide. On some days the driver was interrupted in this way as many as 8 times.

After the piles were driven and cut off, a 6 × 12-in. wale piece was bolted on each side of the piles, entirely around the guard pier, the wale piece being 1 ft. below the top of the piles. Another (but single) wale piece was bolted to the piles, on the outside, at low water. To these wale pieces, 3 × 12-in. sheeting planks were spiked upright; and two more lines of 6 × 12-in. walings were bolted through the sheeting and inside wale pieces, to hold the sheeting in place. The 1-in. bolts were countersunk. The timber for the wale pieces was yellow pine in 16-ft. lengths, and had to be scarfed with a 12-in. ship lap on each end, and drift bolted twice. This scarfing was expensive work, beside causing a 6% loss of timber at the scarfs. If longer lengths than 16 ft. had been used, the cost of labor and the waste of timber would have been less. Beside the wale pieces and sheeting, there were 6 × 12-in. timbers bolted on each side of every fifth bent of piles; and the center piles of the bent were capped, lengthwise of the guard

pier, with a 12 × 12-in. cap. There were nearly 30,000 ft. B. M. of yellow pine timber all told, which cost $23 per M delivered.

For this timberwork the same crew was used as for pile pulling and driving, except that one more timberman, at $1.80, was employed, making the daily cost $17.70. The crew averaged only 1,300 ft. B. M. per day, at a cost of nearly $14 per M for framing and placing all the timber. They were slow workers, and there were delays due to navigation.

Measurement of Timberwork.—Timber is sold by the 1,000 ft. B. M. (thousand feet board measure). A common abbreviation for 1,000 ft. B. M. is the letter M. One foot board measure is 12 ins. square and 1 in. thick, which is 1-12 cu. ft. To estimate the number of feet board measure in a sawed stick, multiply the end dimensions (in inches) together and divide by twelve, then multiply this quotient by the length of the stick (in feet). For example, in a 10 × 12-in. stick, 16 ft. long, there are:

$$\frac{10 \times 12}{12} \times 16 = 160 \text{ ft. B. M.}$$

Timberwork is paid for at a specified price per M for the timber measured in the work. The contractor must be cautious to make allowance for wastage in framing the timber. Scarf joints, for example, may cause a wastage of 6%. If bridge flooring planks are laid diagonally for a 16-ft. roadway, there is a wastage of about 5% when the ends are sawed off on line with the outer stringers.

Timber is usually sold in lengths containing an even number of feet, as 10, 12, 14, 16 ft. In examining plans, the contractor should be careful to note whether the dimensions are such as to require the use of even lengths or not, for a careless engineer or architect may so design a structure as to cause a large wastage of timber.

In measuring dressed lumber, remember that the thickness used in calculating the number of board feet is not the actual thickness of the dressed board, but the thickness of the original stock from which the dressed board was made. So also the width of a tongue and grooved

board is not its actual face width, as laid, but it is the width of the original board.

Cost of Manufacturing Lumber.—A contractor will often find it profitable to cut and saw lumber. A 20-HP. portable engine will run a small saw mill, and with a crew of 5 men the output will be about 8,000 ft. B. M. of 3-in. plank per day. If the wages of the 5 men are $10 a day, and the rental of the engine and saw is $10 more per day, the cost of sawing is about $2.50 per M. The price of the timber as it stands before cutting, is called the stumpage price, and this ranges from $1 to $5 per M. The cost of cutting and skidding hemlock logs, I have found to be about $1 per M, half of which is for cutting and the other half for skidding, wages being $1.50 a day. The total cost of sawed plank in one case was as follows:

	Per M.
Stumpage	$1.50
Cutting	0.40
Skidding	0.60
Sawing	2.50
Total per M	$5.00

Cost of Creosoting.—In "The Polytechnic," March 31, 1905, Mr. O. T. Dunn gives the following data: Creosoting costs $15 to $20 per M. Assuming that two 6-ft. cylinders 100 ft. long are used, the capacity of each cylinder is 16,800 ft. B. M. The total plant will cost, say, $80,000. If the timbers are to be impregnated with 20 lbs. of creosote per cu. ft., it will take about 36 hrs. for a run, and the annual capacity of the plant will be nearly 7,000 M. If the interest and depreciation of the plant is assumed at 10% we have $8,000 ÷ 7,000 = $1.14 per M chargeable to this item. The labor will cost about $3.75 per M. If the oil costs 8 cts. per gal., and 20 lbs. be used per cu. ft., the cost of the oil is $15.33 per M. This makes a total of $20.22 per M. If 16 lbs. of oil per cu. ft. are used, the cost of oil is $10.26 per M, thus reducing the total cost by $5. If the plant is not worked to its full capacity, the interest charge per M becomes greater.

Treated with 20 lbs. of oil per cu. ft., piles in the bridge of the L. & N. R. R., over the mouths of the Pascagoula

River, have been in the structure 28 years, and will be good for many years to come. These piles are subject to attacks of the teredo (Novalis), where uncreosoted piles 1½ ft. in diameter have been cut off by the teredo in a single year.

Beech ties impregnated with 12 lbs. of oil per cu. ft. have lasted 30 years on the Eastern Railway of France.

The specific gravity of creosote is 1.1, or about 10% greater than water.

Cost of Loading and Hauling Timber.—One man, assisted by the driver of a team, will load 1 M of 2-in. plank onto a wagon in about 16 mins. These same two men will unload in 12 mins. With wages at 15 cts. per hr. per man, the cost of loading is 8 cts. per M, and unloading is 6 cts. per M. On short hauls, where the team is idle during the loading and unloading, it is necessary to add 7 cts. more per M for lost team time, if the two horses are worth 15 cts. per hr. This makes a total of 21 cts. per M for loading and unloading a wagon, including lost team time. Green timber weighs from 3 lbs. to 5 lbs. per ft. B. M., depending upon the kind. Assuming 4 lbs., as an average illustration, we see that 1 M weighs 2 tons, which is a good load for hard earth roads in first-class condition. If the wages of a team and driver are 30 cts. per hr., and the load is 1 M, and the speed going and coming is 2½ miles per hr., the cost of hauling is nearly 25 cts. per M per mile measured one way from loading point to unloading point. On muddy earth roads, 1 ton, or ½ M is often a good load; then the cost of hauling is nearly 50 cts. per M per mile. I have known earth roads to be so bad that hauling cost 75 cts. per M per mile.

Sawing, Boring and Adzing.—In heavy timberwork the cost of framing consists mainly in sawing, boring and adzing the sticks. Where a large number of sticks are to be sawed to the same length it generally pays to install a small power saw; but on jobs of moderate size the customary practice is to frame the timbers with a cross-cut saw operated by two men. Using a sharp saw and working rapidly two men can cross-cut a 12 × 12-in. oak stick in 3 mins., but it is generally safer to allow 5 mins. to cover delays.

When a timber is to be notched, or scarfed, a cross-cut saw is used to cut to the bottom of the scarf, then a hatchet or adz is used to cut away the wood roughly, and an adz is used to dress the face. I have seen poor foremen permit workmen to use chisels instead of adzes, thus "making the job last."

A "dap" is a shallow notch cut in a stick.

Mortise and tenon joints are no longer used by those who know how to design economic and durable timber structures. Dowel pins and drift-bolts have largely replaced the old mortise and tenon.

In boring holes for bolts, there are three methods commonly used: (1) Boring by hand with ship augers; (2) boring vertical or inclined holes of moderate depth with hand-power boring machines; and (3) boring with augers operated by compressed air.

A man with a ship auger will bore a 1¾-in. hole in oak, 12 ins. deep in 5 mins. Using a geared boring machine, a man will bore a 1-in. hole 12 ins. deep in 2 mins., by hand. With a pneumatic auger a man will bore a 1-in. hole 3½ ft. deep, in yellow pine chord members of a trestle, in 5 mins. of actual boring time, but 2 mins. more must be added for cleaning the shavings out of the hole, and moving to the next hole, making 7 mins. in all for 3½ ft., or 2 mins. per ft. This is the most economic method of boring where much work is to be done. For cost of operating pneumatic machines, see section on Bridges and Painting.

Mr. W. E. Smith states that in building an ore dock three pneumatic boring machines were used. The air was supplied by two 9-in. Westinghouse locomotive air pumps, through 1,200 ft. of 1½-in. pipe in one direction of the dock and through 1,000 ft. of 1½-in. pipe in another direction to the framing yard. For air receivers there were one locomotive air reservoir on the dock and one in the framing yard. The air pumps had to work so fast to supply air that a stream of water had to be kept running over their valves to keep them cool. It would require a 20-HP. boiler to supply steam for one of the air pumps working at such a speed. While these air pumps use a good deal of steam, they are very convenient, for they are light, easily moved and can be bolted up anywhere to

a wall or post. The pneumatic borers were run with a pressure of 60 to 90 lbs., and gave great satisfaction.

Methods and Cost of Building a Railway Trestle.—A trestle on the Indiana, Illinois & Iowa R. R., near Streator, Ill., was destroyed by a tornado in July, 1903. The right-of-way was quickly cleared by a large gang of trackmen and a new trestle built, using about half of the old timber, all of which had to be framed over again as the bents were made of different heights. The new trestle was 854 ft. long, consisting of 60 bents spaced 14 ft. center to center. Of these bents 43 were double-deck bents, the upper bents being 20½ ft. high, and the lower bents averaging 21 ft. The remaining bents were single-deck. The force averaged 70 bridgemen (carpenters) and 190 trackmen (laborers), and a few teams. This force cleared away the wreckage, and built the new trestle complete in 7 days, not including 1½ days spent in getting men to the site of the work. There were 351,000 ft. B. M. in the new trestle, including ties, and the cost of clearing the site and building the trestle was $11.85 per M for labor of bridgemen, trackmen and a few teams. The wages were probably about $1.50 per 10-hr day for trackmen, and $2.50 for bridgemen. The new timber cost $27 per M.

"The mortise and tenon is a back number" on railway trestle work, so the principal tools used were the two-man cross-cut saw, the adz, and the ship auger. The sills were dapped ½-in., and the ends of the posts were framed to 11½ ins. square, ensuring a perfect joint.

The posts were sawed off square, dapped into the cap and driftbolted, and toenailed to the sill with eight ⅝-in. × 10-in. boatspikes in each post.

A peg was driven and numbered to mark the center of each bent, and small stakes were set on each side to mark the location of the plumb legs and batter posts. The ground was then dug to a level surface around each of the four pegs, but no particular care was taken to dig the ground to the same level at all four pegs. Differences in level were made up by using blocks for cribbing under the sills. These blocks were leveled on top by digging earth out from under them where necessary, which did away with adzing or shimming the sill. The blocks under each

bent consisted of eight pieces 4 ft. long, two blocks under each post, giving a ground bearing of about 45 sq. ft. per bent.

When a foundation of blocking and the lower sill were in place, the posts and cap for a bent were dragged by teams to the site of the bent and rolled over into position just ahead of the foundation. The sill was rolled over on its side; the plumb posts were butted against the dapped places and toenailed, being centered from the grading pegs. The batter posts were laid near their proper places (but not toenailed), and the cap was drift bolted to all four posts, holes having already been bored in the cap. The cap and sill were held tight to the plumb post with chains and with "right and left screw-pulling jacks." Then the batter posts were crowded in at the bottom and toenailed to the sill. The bent being assembled, one sash brace and two sway braces were spiked across the upper face of the bent as it lay blocked up a few feet above the ground. Four ⅜-in. × 8-in. boat spikes were used at each intersection. The bent was then ready to be raised. A set of double tackle blocks was made fast at each end of the cap and anchored to the cap of the preceding bent which had already been erected and securely braced. The pulling ropes ran through snatch blocks fastened to the sill of this preceding bent, and a team was hitched to each of the two pulling ropes. The team up-ended the bent easily. A subbing rope around the cap, and anchored to any convenient anchorage, prevented the bent from going too far and tipping over. And two temporary struts from the sill of the preceding bent to the sill of the bent that was being raised, prevented the bent from sliding while being raised. When erected, the bent was pinched over so as to be centered on the alinement stake; then plumbed and tied to the preceding bent with sash braces and sway braces. The bents were plumbed by eye, or by lining the posts up with a plumb line string held at arm's length. It was necessary to plumb the bent from both sides. A small gang followed the erectors, putting on the remaining sash braces, sway braces, tower braces and A-braces.

Teams were used for hoisting the framed timbers for

the top series of bents, from the ground to the top of the lower series of bents, where they were assembled and erected practically as above described. To hoist the timbers for the top series of bents, a gin-pole was erected. The gin-pole was 40 ft. high, and consisted of two 3 × 12-in. pieces, 28 ft. long, with another piece spiked between them so as to give a total length of 40 ft. This gin-pole was securely chained to one of the lower bents. At first a series of snatch blocks was used in hoisting the timbers, but this proved too severe on the teams and double blocks were used to multiply the power.

The 8 × 16-in. stringers were run out on the trestle on dollies pushed along run planks. They required but little framing. The ends were cut off so that the joint came over the middle of the cap, and the end of any stringer more than 15½ ins. deep was adzed off to that size, to give an even bearing for the ties. The stringers were then turned over flatwise, and piled three deep (breaking joint) and bored. Then they were lifted apart and 2-in. cast iron packing washers slipped in between, and the bolts were entered and tightened. Sections of stringers 200 to 300 ft. long were bolted together, and then turned over into position. To turn a section over, a stout lever, 10 ft. long, was chained to one end of the section. A set of double blocks and tackle fastened to the end of this lever quickly turned the section over.

In boring the holes through the stringers each man averaged 80 ft. of holes bored per day, that is 40 holes 2 ft. long.

The ties were hoisted from the ground by teams, using gin-poles.

The foregoing description has been prepared from data given by Mr. W. R. Sanborn.

Cost of a Timber Viaduct.—Mr. S. D. Mason gives the following data relating to a high timber viaduct on the N. P. R. R. in the Rocky Mts., near Missoula. The viaduct contained 1,000 M of Norway pine, 75% of which was sawed by contract and the rest hewed. The saw mill was put up near the work and all the timber was framed at the mill. The viaduct was 866 ft. long, and 227 ft. high for a distance of about 150 ft. at the center. It consisted of

8 timber towers supporting 7 Howe truss spans of 50 ft. each. On each side of these were M bents supporting straining beams of 30 ft. span each. The timbers were erected by 2 to 4 gangs of 16 men each, a stick at a time. The heaviest stick weighed 1,700 lbs. Both horse and steam power were used for hoisting. The chords of the Howe trusses consisted of two 6 × 12's and one 8 × 12. They were placed and the diagonal braces put in, beginning at the center, the chords being temporarily held by struts and guy lines. It was found impracticable to raise the trusses bodily. Fir angle blocks were used, but their subsequent shrinkage led finally to the building of new Howe trusses. Work was begun Jan. 1, 1882, and completed in 171 days. Laborers and carpenters received excedingly high wages, $6 to $7.50 a day, which accounts for the high cost of $37 per M for framing and erecting. At ordinary wages the labor would have cost about $12 per M. The erecting gangs struck for $10 a day when within 30 ft. of the top, and their wages were raised, but it is not stated how much. The following was the cost of the viaduct:

869 M, at $27	$23,463
101 M, at $16	1,616
87,120 lbs. wrought iron, at 5¾ cts.	5,010
29,940 lbs. cast iron, at 3¼ cts.	973
117,060 lbs. hauled 80 miles, at 2¾ cts.	3,220
Wages of carpenters and laborers	36,336
Salaries of engineers	3,137
Traveling, office and sundry expenses	1,007
Supplies for men	2,860
Blocks, ropes, chains and wrenches	1,300
40 horses, 90 days, at $1	3,600
Hay and oats for same	2,700
Rent of land and land damages	400
Total, at $88.27 per M	$85.622

Cost of Building an Approach to a Bridge.—Mr. B L. Crosby gives the following cost data on the building of a timber trestle approach, 2,960 ft. long, to a double track bridge across the Missouri River, in 1893. The trestle was

built by company men. In the trestle there were 1,438 M of yellow pine, 35,220 ft. of piles, and 97,552 lbs. of iron (70 lbs. per M of timber). The cost of unloading, handling and driving piles, including all material and labor (except the cost of the piles themselves) was 13.7 cts. per lin. ft. The cost of unloading, framing and erecting timber, was $7.42 per M.

Cost of Building a Trestle and a Bridge Under Traffic.—An old railway trestle was rebuilt under a traffic averaging one train per hour. The trestle was 300 ft. long and 50 ft. high at the center. The labor of rebuilding this trestle cost $9.90 per M, including taking down and piling up the old trestle timbers. There were 5 men and a working foreman in the gang; 2 men at $2 a day each, 3 men at $1.75, and 1 foreman at $60 a month.

This same gang built a Howe truss railway bridge under traffic at a cost of $28 per M for labor. The cost of framing and placing 30 M of oak ties and guard rails on three bridges was $12 per M.

Cost of Wagon Road Trestles.—The author's records show the following costs of building a dozen or more trestles in the State of Washington. The trestles were for highway use, and had a 3-in. plank floor, 16 ft. wide, resting on 7 lines of 4 × 14-in. stringers. Bents were spaced 20 ft. apart, three 10 × 10-in. posts to a bent dapped into and doweled to caps and sills. Sills were of hewed cedar 10 × 15 ins. Caps were 10 × 12 ins. × 18 ft. Sway braces were of 3 × 6-in. stuff spiked to the posts and sill. The supports for the hand rail consisted of 4 × 4-in. posts, 4½ ft. long, spaced 10 ft. apart and bolted to the outer stringers which in turn were drift bolted to the caps. The top or hand rail was of 3 × 4-in. stuff, and the hub rail was 2 × 8 ins. There was no mortise and tenon work, and the framing was of the simplest type. The bents were framed flat on the ground and up-ended to place by using blocks and tackle operated by hand power. The flooring and stringers were conveyed to place by dollies. The work was done by subcontractors with few carpenters, and in all cases was handled with excellent judgment and with rapidity. To frame and erect a trestle 60 ft. long, consisting of two bents and two bank sills, required 4 men only 1½ days.

This trestle contained 7 M, of which 5 M were in the floor system (floor and stringers). Three of the gang were laborers, at $1.50, and one was a carpenter, at $2.50, making the daily wages $7 for the gang, so that the cost of building this trestle was only $1.50 per M. This cost was distributed as follows: $4 per M for framing and erecting the bents and the hand railing; 50 cts. per M for laying the stringers and the floor plank. This laying of stringers and plank, where there is nothing to do but to deliver them on dollies, toenail the stringers to the caps, and spike the floor plank to the stringers, can be done very cheaply by common laborers skilled enough to drive nails.

It is not necessary to notch the stringers in order to secure alinement of the tops of the stringers for the plank floor, because in such timberwork perfection of alinement causes a needless waste of labor.

A gang of 3 laborers, on another trestle, laid a floor system containing 15 M of plank and stringers in 1½ days, at a cost of 50 cts. per M.

On another trestle 260 ft. long, it took 4 men 3 days to lay 23 M of stringers and plank in the floor system, at a cost of nearly $1 per M. These men were much slower.

On another piece of road work, where we used round timber for the posts and sills, a gang of 9 men and a team cut and delivered all the necessary timber from the forest, erected and sway braced the bents of three trestles, having a total length of 440 ft., in 12 days. There were 7 framed bents, 12 pile bents (36 piles 20 ft. long, driven 5 ft.), and 6 mud sills in these 3 trestles. The piles were driven with a small horse power pile driver. Seven of these men were laborers, two were carpenters and bosses. The timber in the bents was not accurately measured to determine the number of board feet, but the approximate cost, including the piles, was less than $16 per M for the bents. I consider this an excellent record, and one not to be equalled except under the best foremanship and with willing, intelligent laborers.

Cost of 160-ft. Span Howe Truss Bridges.—In 1894 the author designed, and built by contract, two highway bridges over different points on the Noaksack River, Wash-

ington. Each bridge had a 16-ft. roadway, a clear span of 160 ft., and a depth of truss of 30 ft. at the center. The bridge was designed to carry 100 lbs. per sq. ft. of roadway. The trusses were a modified type of Howe truss. having upper chords that were not horizontal but sloped up from both end posts to an apex at the center, like a roof truss. This design very materially reduced the amount of iron, which was an important factor. Each chord was made of three parallel timbers, each 6 × 14 ins., bolted together. Panels were 20 ft. long. The floor was of 3-in. cedar plank, for lightness and durability. The rest of the timber was Washington fir. The bridges rested on pile abutments, which were protected by log cribs filled with field-stones. Each bridge contained 40 M of timber, of which 23 M were in the trusses and braces, and 17 M in the floor system. No piles were driven for falsework, although the river was 4 to 6 ft. deep and swift; but two-post bents were put up just back of each panel point. These bents were made of round timber, and were erected by first dropping into the water pairs of long-legged saw horses on each side of the proposed falsework, and laying run planks on the horses for men to walk on. A false-work can thus be built with great rapidity and cheaply, and in spite of the weight coming upon the posts of each bent the settlement in the gravel bottom was very slight, and easily taken up by wedges under the lower chords. There is always danger, however, that a sudden flood will undermine the falsework, and this happened at one of the bridges, causing it to fall during construction. No upper falsework, except a light staging at each end post and at the center, is needed with this type of truss, provided long sticks of timber can be secured; for with chord sticks 62 ft. long (in a bridge of this size) it is possible to lift, first one end, then the other, of the upper chord sticks and support them upon the light staging at each end, until the diagonal struts are placed.

The trusses must be first framed and bolted together, flatwise on the ground, then unbolted and erected piece by piece. The timbers were pushed out onto the false-work on dollies, and lifted with block and tackle, using a gin-pole where necessary; all this handling being by

hand without a hoisting engine. Although the following record of low cost will be hard to equal, it serves to show what can be done with efficient labor under a good bridge foreman.

Cost of 160-ft. Span Bridge.

Materials:

40 M timber, at \$7 on cars	\$280.00
40 M timber hauled 3 miles, at \$250	100.00
3,970 lbs. iron rods; 662 lbs. bolts; 769 lbs. gib plates; 326 lbs. drift bolts; total 5,727 lbs., at 3¼ cts.	186.10
14 cast iron angle blocks, 1,316 lbs., at 2¾ cts..	36.20
613 cast iron washers, 613 lbs., at 2½ cts.	15.30
Lag screws, nails, etc.	9.90
Freight on iron	14.50
Total bridge materials delivered	\$642.00
30 abutment piles, 30 ft. long, at 5 cts. per ft.	45.00

Labor:

Framing trusses, 6 carpenters 7 days, at \$2.50..	\$105.00
Getting out timber for falsework and building driver	40.00
Driving 30 piles, 6 men and 2 teams, 9 days	150.00
Building two log cribs	75.00
Erecting lower falsework, 8 men, 3 days	48.00
Erecting bridge, 4 carpenters and 6 laborers, 7 days	133.00
Laying floor and handrails, 4 carpenters and 4 laborers, 1 day	16.00
Loading, hauling and placing 70 cu. yds. of field-stones in cribs (¾-mile haul)	70.00
Total	\$637.00
Foreman, at \$4 per day	160.00
Grand total labor on bridge and abutments..	\$797.00

Summary:

Bridge materials delivered	$642.00
Piles delivered	45.00
Labor	637.00
Foremanship	160.00
Tools, ropes, etc. (one-half charged to each bridge)	100.00
Total cost of one bridge and abutments	$1,584.00

Deducting the cost of material and labor on the two pile abutments and their cribs, we have left, $1,200 as the cost of one bridge alone.

If we analyze the labor we find that the wages of the foreman amounted to 20% of the total labor expenditure. This is a high percentage, but one often exceeded on small works of this character where delays due to bad weather or lack of materials, add up very rapidly when the foreman is paid by the month for handling a small gang of men.

It will be seen that the carpenter work of framing the 23 M (exclusive of the floor) cost $4.50 per M, to which should be added about $1.00 per M for foreman. Erecting the bridge (exclusive of 17 M of floor) cost $133 after the falsework was built, or nearly $6 per M (4 erectors being carpenters, at $2.50, and 6 laborers, at $1.50), to which should be added $1.50 per M for foreman. This makes a total of $10.50 per M for framing and erecting the 23 M in the bridge trusses, to which must be added $2.50 per M for foreman, and $2 more per M for erecting falsework, if we distribute the labor cost of erecting the falsework over the 23 M. The falsework cost must be estimated for every bridge separately. In this case it was unusually cheap.

The cost of placing the 17 M of flooring on the bridge was less than $1 per M, for there was practically no sawing, adzing or boring to be done—simply running the timber out to place on dollies, and spiking it. This seems an exceedingly low cost, but similar records will be found on page 497. Perhaps no better example will be found in this book to show the necessity of separating plain timber-

work from framed timberwork in analyzing timberwork costs.

The cost of the pile driving was high per pile not only because the driving was very hard, but because of the small number of piles in each abutment, and because of the cost of moving across the river and erecting staging for the driver to rest upon at each abutment.

The cribs around the piles were made of hewn timber taken from the forest near by. Each crib averaged 6 ft. high, 10 ft. wide, and 30 ft. long, containing about 6 M of timber. The cost of cutting this timber, hewing and erecting it, was $6 per M, wages of men being $2.50 a day. To this about $1.50 per M should be added for foreman.

A third crib, built for another bridge abutment, was 10 ft. high, 12 ft. wide, and 35 ft. long, containing about 12 M of hewed timber. It took 5 men 4 days, at $2.50, to cut the timber for and build this crib, which is equivalent to about $4 per M, and to this $1 per M should be added for foreman.

Cost of a Wooden Reservoir Roof on Iron Posts.— A reservoir at Pasadena, Cal., was roofed over in 1899, at a remarkably low cost. I am indebted to Mr. T. D. Allin for the following data: The extreme dimensions of the reservoir were 330 × 540 ft., and 166,000 sq. ft. were roofed. The roof was supported by 551 iron posts made of 2-in. water pipe, capped at the bottom and set in cement. On the top of each of these posts a wooden corbel, 6 × 6 ins. × 2½ ft., was fastened by boring a hole 4 ins. deep in the corbel and driving the pipe into the hole. Each post, about 20 ft. long, was up-ended by hand, after the corbel had been driven on, plumbed and temporarily stay-lathed. Posts were spaced 15¾ and 18 ft. apart. On the posts were laid floor beams made of two 2 × 10-in. plank, overlapped at the ends and spiked together, forming a continuous beam 4 × 10 ins. A gang of 7 men, using movable scaffolding for placing and spiking these floor beams, averaged 1,500 ft. of floor beams per day. On these beams were laid 2 × 8-in. stringers, 16 ft. long. The stringers were overlapped 4 ins. and spiked, and were spaced 6 ft. centers. On the stringers were laid 1 × 12-in. planks, forming the roof. These planks were cut to 12-ft., 18-ft. and 24-ft. lengths,

the planks being laid in forms so as to facilitate accurate cutting without individual measurement of each plank. Similar forms were used for cutting the planks used in the floor-beams. The stringers did not require accurate cutting. All the timber was rough, merchantable Oregon pine. The cost of this roof, covering 166,000 sq. ft., was as follows:

260 M Oregon pine, at $18.70	$4,862
9,373 ft. of 2-in. pipe	987
Nails and spikes	203
Millwork on 551 corbels	27
Cement for footings	6
Engineering	151
Labor, including superintendence	1,004
Total, 166,000 sq. ft., at 4.36 cts.	$7,240

It will be noted that the labor cost about $4 per M. Mr. Allin informs me that about 75% of the work was done by laborers and 25% by carpenters. The laborers received $1.75 for 9 hrs., and the carpenters, $2.50 for 9 hrs. The work was done during hard times and quite a number of the laborers were really carpenters. Carpenters were used on the erection work and on work around the sides of the structure where neatness was required.

More recently Mr. Allin has completed covering three more reservoirs in a similar manner, the only change in design being the spacing of joists 4 ft. apart instead of 6 ft. He believes that the extra expense is justified because there is less warping of the boards. Wages are now (1905) $4 per 8 hrs. for carpenters, and $2 for laborers, and prices of materials are higher, so that it costs 6 cts. per sq. ft. to cover a reservoir.

Cost of a Crib Dam.—Mr. J. W. Woermann gives the following cost data for two crib dams across the north and the south channels of Rock River, at the head of Carr's Island, near Milan, Ill., built in 1894. The north dam is 598 ft. long; the south dam, 764 ft. long. The two dams are connected by a levee 1,000 ft. long. The dams are on a rock foundation, and designed to withstand a head of 4½ ft. The dam is a crib of 6 × 8-in. pine timbers, with a rock

filling. The main part of the dam is 13½ ft. wide, with an apron 6½ ft. wide, making a total base of 20 ft. A filling of clay and quarry refuse is placed against the cribwork on the up-stream side. The main dam and the apron are covered with 4-in. oak plank, and the up-stream face of the dam with two rows of 2-in. pine sheet-piling. From the crest of the dam to the apron the fall is 3 ft.

An area below the north abutment was stripped for a quarry (June, 1894), and the 800 cu. yds. of stripping, together with 300 cu. yds. of riprap, were used for coffer-dams for the north dam. The coffer-dams were made as follows: Cribs, 16 ft. square, were built in line, spaced 14 ft. apart. The cribs were built in shallow water by boring holes in the ends of each timber and dropping the timbers over long upright bolts at each corner of the crib. The top of these cribs was sheeted with 4-in. oak plank and weighted down with bags of sand. Timbers, 6 × 8-in., the ends of which were supported by adjacent cribs, were then shoved down into the water. This furnished a coffer-dam 130 ft. long, and riprap and quarry stripping dumped against the face of the dam could not be washed away. The 4-in. oak plank was then removed and used in the permanent work. Subsequently the riprap, which was placed on the down-stream side of the cribs, was removed and used in the dam. The quarry stripping was placed on the up-stream side of the cribs. The areas enclosed by coffer-dams, were 50 to 200 ft. long, and were kept dry with hand pumps. The water in the river was so shallow that wagons were used to deliver all the materials used in both coffer-dams and main dams.

The carpenter work on the south dam was begun Aug. 7 and finished Aug. 22, working 8 hrs. a day, including Sundays. For this dam about 75% of the rock was quarried from the river bed without requiring explosives. During the construction of the coffer-dam for the south dam the force was 14 teams and 50 laborers (for a few rush days there were 130 laborers), and they were engaged from July 24 to Aug. 4. During the erection of the cribwork for the main dam (16 days) the force was 16 carpenters and 50 laborers, about one-third of the laborers assisting the carpenters in carrying timbers, boring, driving bolts and spikes. The number of teams was the same throughout the work.

The total amount of timber in both dams was 330,190 ft. B. M., distributed thus:

	Feet B. M. North Dam.	Feet B. M. South Dam.
Longitudinal timbers (pine)	47,230	73,550
Transverse timbers (pine)	28,350	46,950
Sheet piling timbers (pine)	7,950	14,610
Plank in coping (oak)	33,540	42,840
Plank in apron (oak)	15,870	19,300
Total	132,940	197,250

The cost of the labor of putting this timber into the dams was $5.80 per M.

The rock filling in the north dam is 1,240 cu. yds.; in the south dam, 2,350 cu. yds. The iron used was:

	North Dam.	South Dam.
Anchor bolts, lbs	1,010	320
Drift bolts, lbs	6,050	9,610
Boat spikes, lbs	4,750	6,050
Wire nails, lbs	300	400
Total, lbs	12,110	16,380

The cost of labor on the two dams was:

	North Dam.	South Dam.
Hauling materials	....	$284
Building coffer-dams	$730	1,055
Preparing foundation	493	818
Carpenter work on dams	949	965
Quarrying rock, filling cribs and grading above dams	1,966	1,971
Engineering, watching and miscellaneous	362	402
Total	$4,500	$5,495

This makes the total cost of labor $9,995 on the two dams. The total cost was as follows:

Labor	$9,995
Rent of land	217
111 M oak	2,919
218 M pine	3,087
28,490 lbs. iron	805
Explosives	151
Total	$17,174

Cost of Two Small Scows.—For use in river work, two small scows were built as shown in Fig. 28. Each scow

was 2 ft. deep, 6 ft. wide, and 32 ft. long. It consisted of four parallel frames made by spiking 2 × 6-in. hemlock to form rough trusses. These frames were 2 ft. apart, and to them rough hemlock sheeting plank was spiked, making deck bottom, sides and ends of a closed box. All the joints, except the deck, were calked with oakum and tarred. Thus very cheap and watertight scows were made. They were strong enough to be used for a floating pile driver, by bolting the

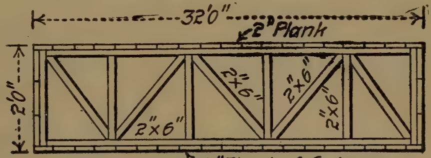


FIG. 28.

two scows side by side; but they were not quite large enough for this purpose and the leaders of the pile driver had to be held with guy ropes, which was a great nuisance. Nevertheless, this rough and light construction proved good enough in every other respect for river work where no logs or other heavy objects could batter the scows. The cost of these two scows was as follows:

3 M rough hemlock, at $11	$33.00
15 lbs. oakum, and necessary pitch	1.50
1 keg nails	2.00
12 days' labor, at $2	24.00
Total for two scows	$60.50

This is equivalent to $30 each for the scows. One carpenter, at $2.50, assisted by one laborer, at $1.50, did the work, which cost $8 per M. During the winter the scows were hauled out of the water, and next spring re-calked with 8 lbs. of oakum, requiring the labor of one man for 14 hrs. Each scow was readily loaded on a wagon for transportation.

Cost of a Flume.—Mr. William H. Hall, in Trans. Am. Soc. C. E., Vol. 33 (1895), describes and illustrates very fully the work on the Santa Ana Canal of the Bear Val-

ley Irrigation Co., in San Bernardino County, California. Wooden stave pipe and a semicircular stave flume, invented by Mr. Hall, were largely used, and cost data are given. The flume is 5½ ft. in diameter, semicircular, made of dressed redwood staves 1¾ ins. thick held by binding rods or hoops (2 ft. 8 ins. apart) passing through 4 × 4-in. wooden cross-yokes. The flume rests on sills or bolsters (10 ft. apart) cut to fit its curved bottom, and these sills are supported on concrete blocks or on wooden trestles according to the locality. A gang of ten laborers and five carpenters and a foreman built the flume. Not a nail was used in its construction. Wages were high, being $2 a day for laborers, $3 a day for carpenters, and $4 a day for team and driver. The cost of erecting the flume, exclusive of trestle work, was $5.75 per M, but this does not include shop work, delivery and calking. The cost of delivering the lumber in wagons was $2.50 per M and subdelivering it on dollies was $2.50 per M more, as the work was in a rough country; hauling costing 37½ cts. per ton mile by contract. The cost of making the sills, and yokes, and dipping all the lumber in coal tar, and calking after erection, came to $3.25 per M, including all timber in the flume, exclusive of trestles. Hence the total labor cost, including delivery and subdelivery, was $14 per M. The lumber was bought for $28 per M.

The cost of framing and erecting timber trestles to support this flume was $13 per M, the rough pine itself costing $19 per M; the cost of delivering it is not given, but was presumably $5 per M. The work was half over before the men became trained to their work, and at no time were they very active or efficient.

The total amount of dressed redwood for the flume staves was 312 M, which required 214,000 lbs. of wrought and cast iron for bands, bolts, etc., or about 700 lbs. per 1,000 ft. B. M. This iron cost 5¼ cts. per lb. At these high prices the cost of the finished flume was about $5 per lin. ft., of which $2.50 was for the flume alone and $2.50 for the trestle supporting it.

Cost of a Coffer-dam and Aqueduct.—In 1840, on the Erie Canal, when skilled laborers were paid $1 per day of 11 hrs. worked (and stone cutters received $2.25 a day—

carpenters' wages not stated), a coffer-dam (built by contract) containing 157,500 ft. B. M. of timber and plank was built with 830 days of skilled labor and a few carpenters. This is equivalent to 190 ft. B. M. per man per day.

In building (by contract) an aqueduct trunk or flume, supported by masonry arches, the timber gang consisted of 2 carpenters to every 1 skilled laborer. There were put in 892,400 ft. B. M. of timber, of which 260,300 ft. B. M. were framed. This required 3,153 days of carpenters and laborers. The average day's work for each man was:

Framing	648 ft. B. M.
Putting in the work	324 ft. B. M.

Cost of Four Caissons.—Mr. B. L. Crosby gives the following on the construction of four piers for a double-track bridge across the Missouri River, for the St. Louis extension of the St. L., K. & N. W. R. R. The foundation work was done by company labor. The masonry piers were founded on pneumatic caissons, each 30 × 70 ft. outside measure, excepting one which was 24 × 60 ft. The caissons were 16 ft. high, including the iron cutting edge, and surmounted with a timber cribwork. This cribwork was 24 ft., 45 ft., 58 ft. and 64 ft. high respectively on the four piers. All the caissons, except one, were built on launching ways on the north side of the river, just above the bridge line. These launching ways were constructed by driving piles, which were capped by 12 × 12-in. timbers running up and down stream, and then the 12 × 12-in. way timbers were drift-bolted to the caps. The ways had a slope of 3 ins. to the foot toward the river, and extended far enough out to allow the caisson to float before being clear of the timbers. Piles were cut off under water with a circular saw, and the drift-bolts, which had been started into the caps before they were sunk, were driven by a ramrod working through a gas-pipe over the drift-bolt. To remove a sandbar at the site of one of the piers, a steamboat was anchored to piles over the pier site, and by the revolution of its paddle wheels washed out a hole 7 to 10 ft. deep. Barges were placed each side of the caisson, and heavy timbers bolted across the caisson, and extending out over the barges. The caisson was towed to its site, and when it struck a sandbar, air was pumped into the caisson to raise it so as to clear

the bar. In sinking the caisson a Morrison sand-pump and a Morrison clay-hoist were used. The greatest depth reached below low water was 101 ft., and laborers in the caisson received $3.50 a day of 2 or 3 hrs. (working 1-hr. shifts) at this great depth. The pneumatic plant used in sinking consisted of two No. 4 Clayton duplex compressors, having steam and air cylinders, each 14-in., with a 15-in. stroke; a Worthington duplex pump, 18½ × 10¼ × 10 ins., and a small dynamo and engine. This plant was set up on the steamboat whose boilers furnished the power. There was also a duplicate plant, which was used part of the time, supported on a pile platform. There were several hoisting engines, a pile driver boat provided with a derrick for handling timbers in building up the cribwork on the caissons. The concrete used to fill the cribwork was 1:2:4 Louisville cement, and 1:3:6 Portland cement. In these four caissons and cribs there were 1,609 M of yellow pine. The cost of framing and building the caissons was $21.93 per M. This includes cost of launching ways, and of material and labor of all kinds; except the cost of the timber itself. It also includes all handling and towing. Carpenters were paid $2.50 and laborers $1.75 per day. There were placed in these caissons 13,285 cu. yds. of concrete requiring 16,035 bbls, of Louisville cement and 4,759 bbls. of Portland cement. The cost of this concrete (broken stone was used) was $5.36 per cu. yd. The average cost of caisson and concrete filling, including cutting edges, shafting, etc., was 34.2 cts. per cu. ft.; the average cost of sinking 9.17 cts. per cu. ft., this average being materially increased due to some rock excavation on one pier where the average cost of caisson sinking was 12.33 cts. per cu. ft. The average cost of caissons was $178 per ft. sunk, ranging from $116 per ft. on one to $259 per ft. on the one where rock was encountered. Work on the first caisson was begun July 30, 1892, and it was launched Aug. 20. It reached bed rock Jan. 2, 1893, at a depth of 89 ft. below low water. The first engine passed over the completed bridge Dec. 27, 1893.

Cost of Making Bodies for Dump Cars.—Some bodies for bottom-dumping cars were made to be mounted on ordinary hand-car trucks, and were used in filling a trestle. The car bodies were made hopper shape, the sides being

4 ft. apart; the ends were 6½ ft. apart at the top and sloping toward the center until they were 4 ft. apart at the bottom. The height of the body was 20 ins., thus giving a struck-measure capacity of 33 cu. ft. Two doors, forming the bottom of the car, were hinged to the two ends of the car body with three 14-in. strap hinges to each door. These doors were each 18 ins. wide and 4 ft. long, and were closed by means of hoisting chains (¼-in. iron) passing around a 2½-in. gas pipe winch which spanned the car from side to side. This 2½-in. gas pipe was stiffened by a 2¼-in. pipe slipped inside. It required 150 ft. B. M. of plank to make each car, and a carpenter (25 cts. per hr.) with a helper (15 cts. per hr.) averaged one car in 7 hrs., which is at the rate of $10 per M.

Cost of Making Tool Boxes.—A carpenter made two tool boxes of 1-in. matched pine boards in 10 hrs. Each box contained 130 ft. B. M., so that the labor cost was a little less than $10 per M, wages being 25 cts. per hr.

Cost of Plank Roads.—Very often the contractor would be enabled to haul much larger loads in wagons if he were to build plank roads up certain short steep ascents, or up out of the pit. The planks need not be spiked to the stringers. Plank for such roads should be 8 ft. long and 3 ins. thick. Contrary to general opinion cedar makes an excellent plank road, for its surface soon becomes a thin mat of wood fibres and dirt that protect the body of the plank. Either three lines of 4 × 6-in. or two lines of 3 × 12-in. cedar stringers should be bedded in the ground and the plank laid upon them without spiking. In the State of Washington the writer found the cost of building the very best of these plank roads to be as follows: Three skilled laborers bedding three lines of 4 × 6-in. stringers in clay, laying and spiking 3-in. plank, averaged 15,000 ft. B. M. per 10-hr. day. In sand these men averaged 18,000 ft. B. M. per day. They were hustling, as they received 50 cts. per 1,000 ft. B. M. for laying this road, plank being delivered alongside. Over such a road a team can pull as much as on the very best asphalt pavement. The "trick" about building a good plank road is to bed the stringers, not leaving them on top of the ground. The road then is

firm and great loads can be hauled over it, so long as it is kept in good condition.

Since in temporary roads the spiking may be omitted, and as a matter of fact it should be omitted even on permanent roads, we see that the plank may be used over and over again for different jobs; but if the road is worth laying at all it is worth laying well in the first place.

SECTION X.

COST OF ERECTING BUILDINGS.

Estimating Quantity of Lumber.—Lumber is measured in feet board measure, as explained on page 487.

There are 15 or more associations in America having rules governing the inspection and classification of lumber. In an editorial article on timber specifications, Engineering News, Feb. 23, 1905, p. 203, I have given the addresses of ten of the most important associations, and of these ten the following three have printed rules that are particularly valuable to have: The National Hardwood Lumber Association, Chicago; Southern Lumber Manufacturers' Association, St. Louis; Mississippi Valley Lumbermen's Association, Minneapolis, Minn.

In building a house, there is always a considerable percentage of waste lumber. Then, too, there is the loss in surface area in forming tongues and grooves at the mill, and in dressing the edges. Therefore, after computing the exact number of pieces, or the exact area, as shown in the plans for the building, it is necessary to add considerably to the lumber bill to cover the waste.

To estimate the number of *joists* for each room, count the actual number and add 1 joist; for an extra joist is needed for the wall. Joists are nearly always "bridged," and for this purpose 2 × 4-in. stuff is used. The "bridging" is the inclined bracing between the joists.

Allow 25 lin. ft. of 2 × 4-in. bridging for each "square" (100 sq. ft.) of flooring. Where 2 × 12-in. joists are placed 16 ins. apart, it will be found that the 2 × 4-in. bridging amounts to about 9% of the number of ft. B. M. of joists.

On a plain roof count the number of *rafters* and add 1 extra.

In estimating the number of *studs* for walls and partitions, allow 1 stud for every lineal foot of wall or partition where studs are "spaced 16 ins. centers," that is 16 ins. center to center. This seemingly large allowance is made to cover the doubling of studs on corners, doors and windows. For a stable or a shed no such extra allowance need be made.

To estimate the quantity of *sheeting* or of *shiplap*, calculate the exact surface to be covered, deducting openings, then add the following percentages:

	Sheeting.	Shiplap.
For floors........................	$\frac{1}{7}$ or 15%	$\frac{1}{6}$ or 17%
For sidewalls....................	$\frac{1}{6}$ or 17%	$\frac{1}{5}$ or 20%
For roofs.........................	$\frac{1}{5}$ or 20%	$\frac{1}{4}$ or 25%

Sheeting is laid with 2-in. spaces on cheap roofs, then deduct accordingly. Sheeting and shiplap are sometimes laid diagonally, then add 5% to the above figures to cover waste in sawing both ends.

Remember that lumber comes in lengths of even feet, and, excepting Oregon fir, 16 ft. is the maximum stock length. Examine each area to be covered to see whether a given number of standard lengths will cover it, or whether there will be a waste on each length.

To estimate the amount of *siding*, calculate the exact surface, deducting openings, and add ⅓, or 33%, if 6-in. siding with 4½ ins. to the weather; but if it is 4-in. siding add ½, or 50%, to the actual surface.

There are two classes of *flooring*, namely, "dressed or square edge flooring," and "dressed and matched flooring." The square edge flooring ordinarily has a face width about ½ in. less than its nominal width; thus, a piece of 6-in. square edge flooring has a face width of 5½ ins., and a piece of 4-in. flooring has a face width of 3½ ins. The loss in the case of the flooring with 5½-in. face is 1-11; and in the case of the 3½-in. face, the loss is 1-7. But in addition to these mill losses, there is generally waste owing to bad ends, etc., so that after estimating the exact area of floor, add the following percentages:

For 6-in flooring, add..............................	$\frac{1}{9}$ or 11%
For 4-in. flooring, add.............................	$\frac{1}{5}$ or 20%

The following gives a fair extra allowance where dressed and matched flooring is to be laid:

For 6-in. flooring, add...........................	$\frac{1}{6}$ or 17%
For 4-in. " "	$\frac{1}{4}$ or 25%
For 2¼-in. " "	$\frac{1}{3}$ or 33%
For 1¾-in. " "	$\frac{5}{12}$ or 40%

Remember that if the flooring is to be laid under partitions, due allowance must be made. If the architect has so spaced the joists that full standard lengths can not be used, there may be a very large waste not included in the above allowances; thus, if the width of room is such as to require flooring 12 ft. 2 ins. long, it will be necessary to buy flooring 14 ft. long, and saw off nearly 2 ft., which is wasted. Flooring less than 1 in. thick is estimated as being 1 in. thick.

Ceiling and *Wainscoting* are estimated just as dressed and matched flooring is estimated.

Cost of Buildings per Cu. Ft.—In order approximately to estimate the cost of any proposed building for which plans have not yet been prepared, it is convenient to estimate the cost in cents per cubic foot. In the following examples the cubic contents are computed from the cellar floor to the roof (if the roof is flat), or (in a pitch roof) to the top of the attic walls that are finished or may be finished; but air spaces and open porches are not included Measurements are from out to out of walls and foundations.

The following figures were compiled by Mr. James N. Brown, of St. Louis, and form part of the instructions to insurance adjusters:

Country property:	Cts. per cu. ft.
Frame dwelling, small box house, no cornice	4
Frame dwelling, shingle roof, small cornice, no sash weights, plain................	5 to 6
Brick dwelling, same class	7 to 8
Frame dwelling, shingle roof, good cornice, sash weights, blinds (good house)....	7 to 8
Brick dwelling, same class	9 to 10
Frame barn, shingle roof, not painted, plain finish	1½ to 2½
Frame barn, shingle roof, painted, good foundation	2½ to 3

	Cts. per cu. ft.
Frame store, shingle roof, painted, plain finish	5 to 7
Brick store, shingle roof, painted, good cornice, well finished	7 to 9
Frame church or schoolhouse, ordinary	5 to 7
Brick church or schoolhouse, ordinary	8 to 10

If slate or metal roof, add ¼ ct. per cu. ft. to the above.

The following costs may serve as a rough guide for buildings of their respective classes built in the Middle West:

	Cts. per cu. ft.
Stores and flats	11
Warehouse, 5 story, mill construction	7
Office building, fine, fireproof, Chicago	30
Office building, wood construction	20
Library, fine, fireproof	35
Hospital, fine, fireproof	25
Hospital, fireproof, no partitions	15
Hospital, wood, no partitions	7
Hotel, fine, fireproof	50
Hotel, ordinary	20
Residence, fine, brick, not fireproof	20
Residence, fine, stone, not fireproof	35
Residence, common, brick, 9 rooms	10

Residence, frame, without modern improvements, $350 per room.

Residence, frame, with modern improvements (hardwood and slate), $500 per room.

Cost of R. R. Buildings per Sq. Ft.—It is often convenient to estimate the cost of railroad buildings in dollars per square foot of ground covered by the building. The following costs will serve as examples for similar buildings in the Mississippi Valley region:

	Per sq ft.
Station, frame, with living rooms, on piles	$1.30
Station, frame, with living rooms, stone foundation	1.50
Station, passenger and freight, frame, on piles	1.15
Station, passenger and freight, brick	1.80

	Per sq. ft.
Station, modern passenger, brick and stone, slate roof, hardwood finish	$3.50
Lavatory, separate 1-story brick, best plumbing. .	4.00
Store house, brick to window sill, unsheeted studs, covered with galv. iron, 2 stories and basement	1.25
Store house, brick, steel and concrete, heaviest construction, no basement	3.75
Machine and erecting shop, best, concrete, brick and steel	1.80
Boiler shop, best, concrete, brick and steel......	1.60
Power house, best, concrete, brick and steel....	2.75
Blacksmith shop, best, concrete, brick and steel..	1.30
Car shop, best, concrete, brick and steel........	1.60
Coal and iron sheds, best, concrete, brick and steel	1.30
Dry kiln, best, concrete, brick and steel..........	1.00
Coach shop, brick to window sill, studs unsheeted, covered with galv. iron	0.70
Planing mill, ditto	1.30

Cost of Items of Buildings by Percentages.—In any locality, if we select buildings of any given class and estimate the percentage of the total cost chargeable to each

	Frame Buildings.	Brick Residences.	Brick Flats and Stores.	Brick Schools.	Brick Warehouses.	Machine Shops (150 x 400).
Excavation, brick and cut stone....................	16%	36%	38%	48%	50%	15%
Plaster....................	8	6	6½	6	....	....
Skylights and glass.......	....	....	....	....	....	10
Millwork and glass........	21	20	17	10½	7	6
Lumber....................	19	12	11½	11½	18½	6½
Carpenter labor...........	18	10	10	10	9½	4
Hardware..................	3½	3	2½	2½	....	....
Tin, galv. iron and slate.	2½	4½	5	3½	....	1½
Gravel roofing............	....	....	1½	....	2	1½
Structural steel..........	....	....	5½	....	....	45½
Steel lintels and hardware	....	....	....	....	8½	6
Plumbing and gas fitting	7	3	4	4	2	....
Piping for steam, water and power..............	....	....	....	....	....	2
Paint.....................	5	5½	4½	4	2½	2
Total...............	100%	100%	100%	100%	100%	100%

NOTE.—Heating is not included.

item, we find a remarkably small variation. For example, the hardware item in brick residences averages about 3% of the total cost of the building whether the building costs $10,000 or $50,000. For a $10,000 building the hardware costs $10,000 × 3%, or $300. For a $50,000 building, the hardware costs $50,000 × 3%, or $1,500. In making preliminary estimates of cost it is often sufficiently close to estimate one or two of the large items and calculate the rest by percentages. Every builder and architect, therefore, should analyze the actual cost of each item of a number of typical buildings, and reduce the analysis to percentages. Where foundation work is difficult and variable, it is well to exclude the foundations in forming a table of percentages, such as the one on page 514. It is also well to carry the subdivisions of cost still farther; but for the purpose of example, the foregoing table serves to illustrate.

Cost of Erecting 5 Different Kinds of Buildings.—In the following table is given the average cost of timberwork in a number of different buildings. Each building is briefly described in the table, and the cost is the average of all the rough lumber in it, and does not include the work on the milled, or dressed lumber. Only carpenters were engaged on this work, and they handled all the lumber after its delivery in wagons at the site of the work. Wages of carpenters were 40 cts. per hr. No common laborers employed.

Building Number.		Ft. B. M. per man per day of 8 hrs.	Cost per M., wage being $3.20 for 8-hrs
1......	A block of six 3-story "flats," first story veneered with brick; rest covered with slate; an expensive front; towers......	275	$11.60
2......	Same type of building with a plain front..	375	8.50
3......	Three-story schoolhouse, plain; including sheeting, shiplap, and all plain lumber except flooring............................	400	8.00
4......	Three-story business building.............	475	6.80
5......	Heavy warehouse, mill construction.......	550	5.80
6......	A plain two-story building, with a 2-in. flooring roof, and plank under-floors....	385	8.30

Cost of Framing and Placing Lumber.—The following table gives the actual cost of the carpenter work in-

volved in doing the different classes of work enumerated. No common laborers were employed.

	Ft. B. M. per man per day of 8 hrs.	Cost per M., wages being $3.20 for 8 hrs.
Joists: In a four-story brick business block, having steel girders, 3 x 14-in. joists delivered sized, average cost of work on joists and sheeting (not including hoisting which was $2 per M. for second story and up)	550	$5.80
Joists: In a three-story, plain, electric light building, with flat roof, 3 x 12-in. joists, including sizing of joists	400	8.00
Joists and floor: In a warehouse, joists dropped into stirrups, and a heavy plank floor	500	6.40
Bridging: 2 x 4-in. bridging between joists	150	21.30
Sleepers: For a railroad machine shop, 6 x 8-in. sleepers buried in sand	380	8.40
Plank Floor: The 3-in. plank floor laid on the sleepers above described	450	7.10
Purlins: For a warehouse, including hoisting 60 ft.	265	12.10
Plank floor: A 2-in. plank floor laid on purlins that were 6-ft. apart	230	13.90
Sheeting for floors	800	4.00
Sheeting for roof of six-story building	500	6.40
Sheeting on frame building	500	6.40
(NOTE.—If sheeting is laid diagonally, add 15% to the cost of laying.)		
Rafters: 2 x 6-in. rafters for plain gable roof	300	10.70
Rafters: 2 x 6-in. rafters for a hip roof	125	25.60
Roof Boards: Rough boards on a plain gable roof	600	5.35
Roof Boards: Rough boards on a hip roof	400	8.00
Siding: Rough boards on a barn	800	4.00
Studding: 2 x 4-in.	250	12.80
Studding: 2 x 6-in.	350	9.15
Sills and plates: 6 x 8-in., without gains or mortices	400	8.00
Sills and plates: 6 x 8-in., with gains but no mortices	200	16.00
Sills and plates: 6 x 8-in., with gains and mortices.	135	23.70
Platform: A rough timber platform on short posts, around a warehouse, including posts, caps, joists and floor	400	8.00
Board Fence: A close board fence, 8-ft. high (posts already set)	400	8.00

Cost of Laying and Smoothing Floors.—In the following table is given the cost of laying matched flooring, after the joists are in place. All the cost of handling the flooring after its delivery at the building site is included. Where the width of the flooring plank is given, the face width is meant, and it should be remembered that the face width is about ½-in. less than the original stock width of the material before milling. A flooring that is sold by the mills as 4-in. plank, has a face width of 3½ ins. The cost of laying is given in "squares" of 100 sq. ft.

COST OF LAYING FLOORING.

	Squares per man per day of 8 hrs.	Cost per square, wages being \$3.20 per 8 hrs.
Yellow Pine: 3¼-in. face laid on sheeting, including the laying of paper between the sheeting and the flooring and including the smoothing of rough joints in the flooring, in a four-story business block	2	\$1.60
Yellow Pine: 3¼-in. face, including smoothing and sandpapering, in a five-story business block, men worked very hard	1¾	1.80
Yellow Pine: 3¼-in. face, laid direct on joists, no smoothing	3	1.10
Maple: Square edged, 4-in face, doubled nailed, not smoothed, in a warehouse	2¼	1.40
Yellow Pine: 4-in. face, nailed on one edge only, not smoothed, in a six-story warehouse	2½	1.30
Yellow Pine: 3¼-in. face, including smoothing and sandpapering, in a three-story seminary, ground floor	1½	2.10
Ditto: Small upper rooms	1¼	2.60
Maple: 2¼-in. face, laid but not smoothed	2	1.60
Maple: 2¼-in. face, laid but not smoothed, large floor of warehouse	3½	0.90
Maple: 2¼-in. face, laid and smoothed, houses and offices	1	3.20
Maple: 1¾-in. face, laid and well smoothed, houses and offices	¾	4.30
Maple: Smoothing only, not including laying the floor	1	3.20
Oak: Gluing, smoothing, scraping and sandpapering a fine floor, men working hard	¼	12.80
Yellow Pine: 5¼-in. face, 2 ins. thick, tongue and groove, for mill building, not smoothed	2½	1.30
Yellow Pine: 5¼-in. face on bare joists, not smoothed	4	0.80
Ditto: Laid on top of an under-floor	3	1.10
Ditto: Laid on a pitched roof without many angles	2	1.60

Cost of Ceiling, Wainscoting and Siding.—The following table gives the cost of ceiling, wainscoting and siding:

	Squares per man per day of 8 hrs.	Cost per square, wages being \$3.20 per day.
Ceiling of a store	1½	2.10
Smoothing an oak ceiling after laying	⅔	4.80
Wainscoting: cut, put up and finished with cap and quarter round	1¾	1.80
Siding: Plain, 6-in	2¼	1.40
Drop-siding: When window casings and corner boards are placed over the siding	4	0.80
Drop-siding: When joints are made against casings and corner boards	2½	1.30
Lap-siding	3	1.05
Surfaced barn boards	7	0.45

Cost of Shingling.—The following table gives the cost of laying shingles, shingles being well laid with 4½-in. exposure:

	Squares per man per day of 8 hrs.	Cost per square, wages being $3.20 per day
Plain roof	2½	$1.80
Fancy roof	1¾	1.80
Difficult roof, much cutting	1	3.20
Plain side walls	1½	2.10
Difficult side walls	1	3.20

The standard bunch of shingles is supposed to contain 250 shingles averaging 4 ins. wide. Hence if shingles are laid with an exposure of 4½ ins., each shingle covers $4 \times 4\frac{1}{2} = 18$ sq. ins., or 800 shingles to the square. But the cutting for angles, the loss of broken shingles, the double course at the eaves, and the like, necessitate a larger allowance. On plain roofs allow 8% more, and on gables 12% more than the theoretical 800. Estimate as follows:

	Plain Roof. Shingles per square.	Cut-up Roof. Shingles per square.
With 4-in exposure	990	1010
" 4½-in. "	880	900
" 5-in. "	790	810

Cost of Laying Base-Boards.—The amount of baseboard work is computed in lineal feet, instead of board feet. The following costs relate to the actual number of lineal feet, doors and openings being deducted:

	Lin. ft. per man per day of 8 hrs.	Cost per lin. ft., wages being $3.20 per day.
Base-board: In a building with an unusually large number of pilasters	50	6½ cts.
Base-board; Three-membered, hardwood, average number of miters	50	6½ cts.
Base-board: In a plain five-story business block, two-membered base scribed to floor	80	4 cts.
Base-board: In a three-story seminary, narrow birch; fitting to the floor not necessary	100	3¼ cts.
Base-board: Plain, quarter-round at floor	100	3¼ cts.
Moulding: Bed, flat, 3-in	320	1 ct.

Cost of Placing Doors, Windows and Blinds.—The following table gives the cost of labor on doors, windows and blinds:

	Number of hrs. labor on each.	Labor cost of each, wages being 40 cts. per hour.
Windows: To put frames together if stuff comes knocked down	1½	$0.60
Window: Ordinary pine window in a frame building, including setting frame	5	2.00
Window: Same as before, except hardwood	6½	2.60
Window: Ordinary pine window in brick building, including setting frame	6½	2.60
Window: Same as before, except hardwood	9	3.60
Window: 30-light (lights 10 x 14), setting frame, fitting and hanging sash, and putting on hardware, for a machine shop	7	2.80
Window: Same as before, but hung on sash balances	6	2.40
Transom: Fixed	1	0.40
Transom: Hung	1½	0.60
Door: Common hardwood, set jambs, case, hang and finish, including transom	10	4.00
Door: Birch door, complete, for a seminary	7	2.80
Door: Common pine door, 1⅜-in., complete	4½	1.80
Door: Common pine, 1¾-in., complete	5½	2.20
Door: Pine, swinging door, no hardware except hinges	4	1.60
Door: Pine, finish of wide paneled jambs, with transom, for school house	10	4.00
Door: Same as before, but hardwood	12½	5.00
Sliding doors: Pine (framing not included), to finish complete with lining, jambs, casings, and hardware, per pair	32	12.80
Sliding doors: Same as before, but hardwood, per pair	48	19.20
Outside doors: Pine, 6 x 8 ft., door frame, casings, and hardware, complete, per pair	10	4.00
Outside doors: Same as before, but hardwood, per pair	14	5.60
Outside double doors: Opening 12 x 18 ft., in a factory	32	12.80
Sliding doors: Opening 12 x 18 ft., in a barn	24	9.60
Blinds: If fitted before frames are set, per pair	¾	0.30
Blinds: If fitted after frames are set, per pair	1	0.40
Blinds: Plain pine, inside blinds, per set	3	1.20
Blinds: Same as before, but hardwood	5	2.00

The labor cost of bedding and setting 10 × 14-in. lights on a large building was 1½ cts. per light, or 1½ cts. per sq. ft.; and one-twenty-fifth of a pound of putty per lineal foot around the edge of the glass was used. With a deeper rabbet and putty not properly pressed, one-fifteenth pound per lineal foot of glass edge may be used. The cost of setting plate glass is about 7 cts. per sq. ft. Floor and

sidewalk glass may be set for 5 cts. per sq. ft.; skylight glass for 8 cts. per sq. ft.

Cost of Closets and Sideboards.—The following miscellaneous labor costs will serve as a guide: The labor costs are given in dollars and cents, wages being 40 cts. per hour:

	Cost of Labor
Drawers, if dovetailed, each	$1.00
Drawers, 15 ins. wide, 18 ins. deep, including racks and fittings, each	0.80
Shelves, in a storeroom, shelves dadoed into compartments 18 ins, square, per sq, ft. of shelf	0.25
Shelves, in pantry, no dadoing, per sq. ft.	0.15
Closet hooks, on a strip of wood, hooks 12 ins. apart, per lin. ft. of strip	0.06
Sideboard, ash, 8 × 8 ft., drawers, doors, brackets, shelves, mirrors and hardware	50.00
Sideboard, oak, less detail than before	40.00
Sideboard, pine, fairly good	25.00

Cost of Making Stairs.—The labor cost of making a number of different kinds of stairs will be given, labor being 40 cts. per hour. The cost includes the making and setting of the stairs, but does not include mill work.

	Cost of Labor.
Two flights of stairs (for a school), 6 ft. wide, with ceiling rail	$35.00
Three flights of oak stairs (for a hospital), 5 ft. wide with continuous rail	90.00
Three flights of oak stairs (for a seminary)	120.00
Box-stair, long, without landing	9.00
Box-stair, for cellar or attic, if windows are used	10.00
One flight of plain stairs, in a 7-room house	16.00
One flight of fine stairs, in a 9-room house	40.00

Cost of Tin Roofing.—The sizes of tin sheets are 14 × 20 ins., and 20 × 28 ins. An allowance of 1 in. must be made for laps at joints; with sheets 20 × 28 ins., a square (100 sq. ft.) requires 29 sheets. With 14 × 20-in. sheets, allow 63 per square, and 50% more of solder, rosin, etc. A

box of tin contains 112 sheets, and the large sheets of I. C. tin weigh 225 lbs. per box; the I. X., 285 lbs. per box.

One man, at 40 cts. per hr., will lay 2 squares of plain roofing per day. One man will line about 75 sq. ft. of box gutter, or an equal amount of flashing, per day. The cost per square of tin roof was as follows:

	Per square.
29 sheets of I. C. tin, 55 lbs., at 8 cts.	$4.40
5 lbs. solder, at 14 cts.	0.70
1½ lbs. nails, at 4 cts.	0.06
1 lb. rosin	0.04
Labor, at 40 cts. per hr.	1.60
Charcoal	0.10
Painting two coats	1.50
Total	$8.40

A man, at 40 cts. per hr., will put up plain metal ceilings at the rate of 1½ to 2 squares per day, including cornice and centers. On a large room, and plainest kind of work, he may do 3 or 4 squares. Wainscoting, at the same rate.

A man, with a helper, will lay 12 squares of corrugated iron roofing in a day.

Building Papers and Felts.—The cheapest grade of building paper is "rosin-sized" paper. It is not waterproof, and should not be used on roofs, or on walls in a damp climate. It comes in rolls 36 ins. wide, containing 500 sq. ft., weighing 18 to 40 lbs., and costs about 3 cts. per lb.

There are a number of different kinds of waterproof papers used for sheathing under siding or shingles. P. & B. building paper, for example, is coated with a paraffin compound. It comes in rolls 26 ins. wide containing 1,000 sq. ft. The weights per roll are:

Ply	1-ply.	2-ply.	3-ply.	4-ply.
Weight	30 lbs.	40 lbs.	65 lbs.	80 lbs.

Price is 10 cts. per lb.

Common dry felts are made of wood fibers cemented together with rosin. They weigh about 5 lbs. per 100 sq. ft.

The best grades of dry felt are made of wool, and weigh 11 lbs. per 100 sq, ft. when they are ⅛-in. thick; but some brands are 50% heavier than this. The price of dry wool felt is about 2¼ cts. per lb. Such felts are used.

Tar felt, or common roofing felt, is made by saturating common dry felt with coal tar. The weight of a single layer or ply is 12, 15 or 20 lbs. per 100 sq. ft., but the felt is laid in several layers, usually 4 or 5-ply, in making a roof, each layer being mopped with a "composition" of ⅓ tar and ⅔ pitch. The price of tar felt is about 1½ cts. per lb.

There are many kinds of patent roofing felts. Ordinarily they come in rolls 29 ins. wide, and each roll covers a square, allowing 2 ins. for the lap. Nails and cement are supplied with each roll by the manufacturers. The cost of the roofing is $3 to $5 per square, and the cost of laying it is about 1 hr. labor per square, or 40 cts. The weight of such roofing varies considerably, but ordinarily is about 100 lbs per 100 sq. ft.

Cost of Gravel Roofs.—Tar felt, 4 or 5-ply, is first laid, the sheets being mopped with "composition" of ⅓ tar and ⅔ pitch. Screened roofing gravel is spread over the roof. A square of gravel roof costs about as follows:

	Per square.
1-6 cu. yd. (450 lbs.) gravel, at $2.40	$0.40
40 lbs. tar, at 1½ cts.	0.60
80 lbs. pitch, at 1½ cts.	1.20
100 sq. ft. felt, 4-ply, 75 lbs., at 1½ cts	1.13
Labor, at 35 cts. per hr.	0.70
Total per 100 sq. ft.	$4.03

Note: About 20 lbs. of "composition" per square per ply is ordinarily sufficient where sheets are mopped only at the joints instead of all over; but in the above the sheets are assumed to be mopped all over, which takes 50% more composition.

Tar is usually sold by the gallon, or by the oil barrel holding 50 gallons, present prices being 12 cts. per gallon. Tar weighs exactly as much as water, or 8⅓ lbs. per gallon.

Cost of Slate Roofs.—Roofing slate comes in a great variety of sizes, the most common of which are 16 × 8, 16 × 10 and 18 × 9 ins.; but sizes as large as 24 × 14, and as small as 12 × 6, are made. To determine the number of pieces to a square, deduct 3 ins. from the length (for the lap), divide this by 2, multiply by the width of the slate and divide the result into 14,400. A 18 × 9 slate would be estimated thus: $18 - 3 = 15$, which divided by 2 gives $7\frac{1}{2}$; then $7\frac{1}{2} \times 9 = 67\frac{1}{2}$; then $14{,}400 \div 67\frac{1}{2} = 214$ pieces.

Slates are sold by the square, that is a sufficient number of slates to lay 100 sq. ft., each course having a lap of 3 ins. over the head of those in the *second* course below. The price f. o. b. Pennsylvania and Vermont quarries varies according to the grade; but a good No. 1 slate, 3-16-in. thick, can be bought for $5 per square. The freight from Pennsylvania or Vermont to the Mississippi River is about $2.50 per square. Allow about 1% waste, unless the roof is perfectly plain.

The weight of 1 sq. ft. of slate ¼-in. thick is 3.6 lbs. As there are 214 pieces of 18 × 9-in. slate per square of roof; and if it were all ¼-in. thick, the weight would be 868 lbs.; if it were 3-16-in. thick, the weight would be 621 lbs.

Before laying the slate, the roof is covered with paper. A 50-lb. roll will cover 400 sq. ft., and with wages at 40 cts. per hr., the cost of laying the paper is 20 cts. per square. The holes for the nails must be punched in the slate before laying. This may be done by the manufacturers, but it is usually done by hand by the slaters, because if a corner is broken off in transport the slate can be turned end for end, moreover as slate usually comes in three thicknesses it must be sorted anyway before laying, and the punching can as well be done at the same time. One slater, at 40 cts. per hr., with a helper, at 20 cts. per hr., will punch the holes in 10 × 16-in. slates at a cost of 45 cts. per square.

In laying slates, about one laborer is required for two slaters on plain roofs. A slater will punch and lay 3 squares per 8 hrs. on plain straight work, 2 squares on roofs with many hips and valleys, and as low as 1 square on difficult tower work. For fair average work allow 2½ squares per day per slater, and allow 1 laborer

to 2 slaters. This includes punching, and laying paper and slate. The cost of a slate roof, 10 × 16-in. slates, was as follows:

	Per square.
Slate for 1 square	$5.00
Freight (650 lbs.)	2.50
Loading and hauling	0.20
Wastage, 1% of $7.70	0.08
16 lbs. paper	0.50
1 lb. nails	0.05
2½ lbs. of 3d galv. nails for slate	0.10
Slater, at 40 cts. per hr.	1.30
Helper, at 20 cts. per hr.	0.30
Total per square	$10.03

Brick Masonry Data.—The size of common bricks varies widely. I have seen bricks as small as 2 × 3¼ × 7½ ins. used for house building in New York City. In the New England States, common bricks are said to average about 2¼ × 3¾ × 7¾ ins. In most of the Western States, common bricks average 2½ × 4⅛ × 8½ ins. The size of individual bricks in a car load often varies considerably; hard bricks being ⅛ to 3-16-in. smaller than soft (or salmon) bricks. Pressed or face bricks are quite uniformly 2⅜ × 4⅛ × 8⅜ ins. If there is any standard size it may be said to be 2¼ × 4 × 8¼ ins. A thousand bricks, averaging 2¼ × 4 × 8¼ ins. weigh 5,400 lbs., if they weigh 125 lbs. per cu. ft.; and they occupy 43.2 cu. ft. of space, which is equivalent to 23¼ bricks per cu. ft., if no allowance is made for joints. If these bricks are laid in massive masonry with ½-in. joints, about 430 bricks will be required per cu. yd., or 16 per cu. ft.; if laid with ¼-in. joints, 515 bricks per cu. yd., or 19 per cu. ft.

Masons have empirical rules for estimating the number of bricks in a wall. Their rules do not give even an approximation to the actual number, or "kiln count." They often make no deductions for openings, but use a "wall measure" rule, allowing 7½ bricks per sq. ft. (or per superficial foot) for a wall that is a "half brick thick," that is a 4-in. wall. For "one-brick" wall, that is 8 or 9 ins. thick, they estimate 15 bricks per sq. ft. For a "one-and-

a-half-brick" wall (12 or 13 ins. thick), they estimate 22½ bricks per sq. ft. This rule takes no account of the actual size of the bricks, and does not, therefore, give "kiln count," but gives "wall count." We have seen, above, that "standard size" bricks, laid with ½-in. mortar joints, will actually average 16 per cu. ft., as compared with 22½ per cu. ft. "wall count."

If all the broken bricks, or "bats," were thrown away, the wastage would be about 2% with fair bricks to 5% with poor bricks; but it is not often that contractors are prohibited by inspectors from using practically all the "bats."

The cost of loading and hauling paving bricks is given on page 158, and practically the same costs apply to building bricks, except that the latter are lighter. As above stated, the "standard size" hard brick weighs about 5.4 lbs., or 2.7 tons per M, or 125 lbs. per cu. ft. Soft bricks weigh 20% less, but repressed bricks weigh 20% more per cubic foot. With wages at 15 cts. per hr., the cost of unloading cars into wagons is 30 cts. per M, and, unless a dump wagon is used, it costs another 30 cts. per M to unload the wagons.

Cost of Laying Brick.—In building brick walls there are usually 1 to 1½ laborers to each brick mason. The laborers mix mortar and carry mortar and bricks to the masons, using hods for the purpose. A hod holds about 18 bricks, or approximately 100 lbs. The wages of masons and hod carriers vary widely in different cities, but seldom exceed $5 per 8-hr. day for masons and $3 for hod carriers. Very often the masons' unions have forced up their rates of wages, but the hod carriers have not, and may receive but little more than other common laborers. With wages as just given, and one helper to each mason, the labor cost of laying should not exceed $6 per M for common brick, and $10 per M for pressed (face) brick, "kiln count" in both cases.

On a three-story brick hospital, with a carefully laid front (½-in. "shaved" joints), the labor cost was $5.50 per M, "kiln count." There were three laborers to every two masons, and wages were 17½ cts. per hr. for laborers, and 45 cts. per hr. for masons, working 9 hrs. The cost of

the masons' wages amounted to $3.50 per M, and the cost of the helpers' wages was $2 per M. This cost was rather high, due to the number of deep flat brick arches over basement openings, and to the row-lock arches over other openings, as well as a tower and other puttering work.

In building warehouses, where the work was plain, wages being as just given, the cost was $4 per M, "kiln count."

On several large city buildings, in which 15 to 20% of the brick masonry was pressed brick, each brick mason laid the following average number, "kiln count," per 9-hr. day:

Apartment house, 4 stories	1,200
Four-story fronts	1,250
Heavy walls, ground level	1,500
Heavy footings and warehouse basement walls..	3,200

A bricklayer should lay 400 or 500 pressed brick per 8-hr. day. If an ornamental brick front is to be laid, with molded arches, buttresses with bases and caps, etc., the labor of laying pressed brick may run as high as $20 per M.

In veneering a frame building with brick, a mason will average 400 bricks per day.

In building brick arches to support the sidewalk in front of a city building, after the centers were set, each brick layer averaged 1,800 bricks per 9-hr. day; and it required one man to make and deliver mortar and to deliver brick to every two bricklayers. The brick arches were 5-ft. span, 11 ft. long, and 4 ins. thick.

Cost of Mortar.—With lime mortar, mixed 1 part lime to 3 parts sand, it required 0.9 bbl. lime per M of bricks, "kiln count," the bricks being laid with ⅜-in. joints. A common allowance in estimating the cost of mortar, for "standard size" bricks, is 1 bbl. lime and 0.6 cu. yd. sand per M, "kiln count." About ⅓ cu. yd. of mortar is usually allowed per cu. yd. of brick masonry, or 0.7 cu. yd. mortar per M of bricks, when bricks are laid with ½-in. joints. If cement mortar is used, the number of barrels of cement per cubic yard of mortar will be found on page 253. It will seldom require less than 1.6 bbls. of cement per M of bricks, or 0.8 bbl. per cu. yd. of brick masonry, for if the mortar is made leaner it will not trowel well, and cause more loss in labor than is saved in cement.

Rockland, Me., lime is sold by the barrel, 220 lbs. net When shipped in bulk 2½ bu., of 80 lbs. per bu., are usually called a barrel. A barrel holds about 3.6 cu. ft. The average yield of lime paste from the best limes is 2.6 bbls. of paste for each barrel of quick lime. This paste is usually mixed with 2 parts sand by measure. It, therefore, takes about 1½ bbls. of the best quick lime to make 1 cu. yd. of mortar. A poor lime does not make ¾ as much paste as a good lime.

The price of lime is about 60 cts. per bbl.

Cost of Placing Tile Fireproofing.—Hollow tile used for floors or walls, or for protecting steel beams and columns, is measured by the square foot. It is desirable to purchase it from the manufacturers on the basis of the square foot measured in the work. Where the brick layers' wages were 45 cts. per hr., the tile work in a four-story hospital cost 5½ cts. per sq. ft. for the labor on the 10-in. and 12-in. tile floors and roof. This does not include the cost of hauling the tile to the building, but it does include the hoisting and delivery of the tile to the masons. The labor cost of 4-in. tile partitions and tile protection for I-beams and columns was 4½ cts. per sq. ft.

Cost of Brick Chimneys.—On small chimneys and fireplaces the labor costs 2 to 3 times as much per M as on plain wall work. A mason (55 cts. per hr.) and helper will lay 600 bricks in 9 hrs. The labor costs 30 to 35 cts. per lin. ft. for single-flue chimneys, 8 × 8 ins. square and 4 ins. thick; and 50 cts. per lin. ft. for double-flue chimney. There is a wastage of brick of about 5% where the brick fit, or 10% where cutting is necessary.

Cost of High Brick Chimney Stacks.—With wages of masons at 55 cts. per hr., and where the flue is large enough for men to work from the inside, the cost of laying bricks for chimney stacks, 100 to 125 ft. high, is $12 per M of bricks. In one case a stack 150 ft. high, containing 250,000 bricks, cost $7 per M for labor, wages being as above given.

Cost of Rubble Walls.—Basement walls are commonly made of rubble. The best work requires "two-man rubble," that is stone too heavy for one man to lift. A common allowance for a limestone rubble wall is ⅓ cu. yd. sand,

½ bbl. cement, and 2,800 lbs. stone, per cu. yd. of wall. If lime is used, allow ⅓ bbl. lime. A mason and helper will lay 3 cu. yds. in 8 hrs., so that if wages are 50 cts. per hr. for mason and 25 cts. per hr. for helper, the cost of laying is $2 per cu. yd.

For further data, see the sections on Masonry and Concrete.

Cost of Ashlar.—Ashlar in buildings is estimated by the cubic foot. In ordering "raw stone" (uncut stone) for ashlar, give the quarryman the exact number of cubic feet measured in the wall. He will make allowance for the waste in cutting it.

The cost of Bedford ashlar for the moldings, turrets, etc., in an Omaha building was:

	Per cu. ft.
Raw Bedford	$0.65
Cuting, wages 55 cts. per hr.	1.00
Setting in the building	0.20
Washing and pointing	0.05
Total in place	$1.90

It requires about 1 gal. muriatic acid to wash 500 sq. ft. To wash and point the joints costs 3 cts. per sq. ft.

Cost of Wood Lathing.—The standard size of wood laths is ¼-in. × 1½ ins. × 4 ft. There is a special lath made 32 ins. in length. Laths are sold by the 1,000 in bundles of 50 or 100 laths per bundle. A common price is $3 per 1,000 laths. It requires 1,500 standard laths to cover 100 sq. yds. Allow 10 lbs. of 3d fine nails for 100 sq. yds. when joists are 16 ins. center to center. Chicago lathers have fixed 1,250 laths as a day's work per man.

The cost per 100 sq. yds. is as follows:

	100 sq. yds.
1,500 laths, at $3 per M	$4.50
10 lbs. nails, at 3 cts.	0.30
Labor, at $3.20 per 8-hr. day	3.20
Total per 100 sq. yds.	$8.00

This is 8 cts. per sq. yd. There is no uniformity in practice as to deducting window and door openings from the area lathed.

Cost of Metal Lathing.—There are several makes of wire lathing, as well as expanded metal lathing. For plastering, the Expanded Metal Engineering Co., of New York, furnish two styles of expanded metal lath, in sheets $1\frac{1}{2} \times 8$ ft., as follows:

	Lbs. per sq. yd.
"Diamond" lath, Gage No. 24	3.65
"Diamond" lath, Gage No. 26	2.66
"A" lath, Gage No. 24	4.23
"B" lath, Gage No. 27	2.84

The price of these laths ranges from 15 cts. to 20 cts. per sq. yd.

The cost per 100 sq. yds. is as follows:

	100 sq. yds.
100 sq. yds., "Diamond" No. 26	$15.00
10 lbs. staples, at 3 cts.	0.30
Labor, at $3.20 per 8-hr. day	3.20
Total per 100 sq. yds.	$18.50

This labor includes the cost of scaffolding, and is based upon some 6,000 sq. yds. of work. It will be noted that the labor cost is 1.2 cts. per lb. of metal.

Cost of Plaster.—Plastering on laths generally requires three coats, occasionally two coats. The first is the scratch coat; the second is the brown coat; the third is the white coat, or finish. On brick walls the scratch coat is generally omitted.

Plaster is made either with lime or with cement plaster. Cement plaster (or wall plaster) usually consists principally of plaster of Paris. Some plasters are made of lime gaged with Portland cement. Whatever kind of lime or plaster is used, sand and hair are mixed with the plaster. The hair is put up in paper bags supposed to contain 1 bu. of hair when beaten up, and supposed to weigh about 7 lbs. Some cement plasters are sold with the proper amount of hair mixed in. Cement plaster is commonly sold in 100-lb. sacks, four sacks making 1 bbl. A common price is 25 cts. per sack.

In making lime plaster, 1 part of lime paste to 2 or $2\frac{1}{2}$ parts of screened sand is used. About $1\frac{3}{4}$ cu. yds. of

sand are required per 100 sq. yds. of three-coat plaster, and about 4 bbls. of lime, or cement plaster, and 2 bu. of hair.

The cost of 100 sq. yds. of three-coat plaster is about as follows:

	100 sq. yds.
1.75 cu. yds. sand, at $1	$1.75
3½ bbls. lime, or 9 bu., at 35 cts.	3.15
2 bu. hair, at 40 cts.	0.80
100 lbs. plaster of Paris, at 50 cts.	0.50
Labor, plasterers, at 55 cts. per hr	15.00
Total, 100 sq. yds., at 21.2 cts.	$21.20

Cost of Steel Mill and Mine Buildings.—The following is a summary of data given in Ketchum's "Steel Mill Buildings," a book containing much excellent information on estimating steel work:

The drawings for steel mill buildings usually show only the dimensions of the "main members." The estimator usually calculates the weights of these main members and adds a percentage to provide for the weight of the "details." The "details" are the plates and rivets used in fastening the main members together. The weight of the "details" of trusses will commonly be 25 to 35% of the weight of the "main members," being usually nearer 25%. After computing the actual weights of details for a few buildings, the estimator will seldom blunder in computing by percentages.

In estimating the weight of corrugated steel, add 25% for laps where the side lap is two corrugations, and the end lap is 6 ins.; add 15% where the side lap is one corrugation and the end lap is 4 ins. Corrugated steel is usually made with corrugations 2½ ins. wide (from ridge to ridge) and ⅝-in. deep. The thickness of the steel is usually given in U. S. Standard Gage. The following are the weights per 100 sq. ft. of black corrugated steel:

Gage, No.	16	18	20	22	24	26	28
Lbs. per 100 sq. ft.	275	220	165	138	111	84	69

Add 16 lbs. per 100 sq. ft. if the steel is galvanized.

The cost of steel mill buildings is divided into four items: (1) cost of steel; (2) cost of shop work; (3) cost of transportation, and (4) cost of erection. The price of structural steel may be found in current numbers of "Iron Age," published in New York. The price is now (1905) about 1.8 cts. per lb. at New York.

The following are actual shop costs, in a shop having a capacity of 1,000 tons per month, and with labor estimated at 40 cts. per hr., which includes also the cost of management and the cost of operating and maintaining the shop equipment:

Cost of shop-work.	Cts. per lb.
Columns, made of 2 channels and 2 plates, 1,000 lbs.	0.8
Columns, made of single I-beam, or single angle	0.5
Columns, Z-bar	0.8
Columns, plain, cast iron	0.8 to 1.5
Riveted roof-trusses, 1,000 lbs. each	1.2
Riveted roof-trusses, 1,500 lbs. each	1.0
Riveted roof-trusses, 2,500 lbs. each	0.8
Riveted roof-trusses, 3,500 to 7,500 lbs. each	0.6 to 0.75
Plate-girders, for crane girders and floors	0.6 to 1.3
Eye-bars, ¾ × 3 ins. × 16 to 30 ft.	1.2 to 1.8
Eye-bars, large	0.5 to 0.8
Steel frame transformer building, 60 × 80 ft., with 20-ft. posts, pitch of roof ⅓, 55,700 lbs. steel framework, including drafting	1.0
Smelter building, 270 tons, incl. drafting	0.86
Six gallows frames, incl. drafting	1.0 to 2.0
Drafting design of "details" for	
Ordinary buildings	0.1 to 0.2
Headworks for mines	0.2 to 0.3
Roof-trusses	0.3 to 0.4

With skilled labor at $3.50 and common labor at $2 per 9-hr. day, the cost of erecting small buildings is about 0.5 ct. per lb., or $10 per ton, if trusses are riveted and other connections bolted.

The cost of erecting small buildings in which all connections are bolted is about 0.3 ct. per lb., or $6 per ton.

The cost of erecting heavy machine shops, all material riveted, is about 0.45 ct. per lb., or $9 per ton, including labor of painting.

The cost of erecting 6 gallows frames was 0.65 ct. per lb., or $13 per ton.

The cost of laying corrugated steel roof is about $0.75 per square, or $9 per ton for No. 20 steel, when laid on plank sheathing; it is $1.25 per square, or $15 per ton, when laid directly on the purlins; it is $2 per square, or $24 per ton, when laid with anti-condensation roofing. The erection of corrugated steel siding costs $0.75 to $1.00 per square, or $9 to $12 per ton for No. 20 steel.

Cost of Erecting the Steel in Four Buildings.—The costs are given in tons of 2,000 lbs. On a four-story, fire-proof hospital the cost of erecting the steel and cast iron was $4.50 per ton; hand derricks were used, and the work was all done by common laborers, at $1.50 per day. With a steam derrick the cost might have been reduced to $3.50 per ton. On a three-story business block, under the same conditions as before, the store fronts were erected for $5 per ton.

On a large railroad machine shop, with structural steel workers at 40 cts. per hr., the cost of erecting was $8 per ton. In this case the work was all heavy, the lightest truss weighing 5 tons. On train sheds, and where lighter sections were used, and where there were more field rivets to the ton, the cost was $10. Ordinarily there are about 10 field rivets to the ton, and it is safe to allow 10 cts. each, or $1 per ton for riveting alone. There are buildings in which 25 field rivets per ton are required. The foregoing costs of steel erection include unloading from cars, setting derricks and scaffolding.

The cost of erecting large electric cranes is about $3 per ton if put in place directly from the cars. Add $1.50 per ton if unloaded from cars before erecting.

References.—Any one engaged in estimating the cost of very many buildings will do well to consult Arthur's "Building Estimator," Ketchum's "Steel Mill Buildings," and Kidder's "Architects' and Builders' Pocket Book."

The prices of hardware may be obtained from "The Iron

Age Standard Hardware List" ($1), published by The Iron Age, New York City. The current discounts are given in The Iron Age, a copy of which costs 10 cts.

The prices of lumber are quoted weekly in such papers as the "New York Lumber Trade Journal." Different mills issue catalogues giving prices of mill work.

SECTION XI.

COST OF STEAM AND ELECTRIC RAILWAYS.

Cost of Making Hewed Ties.—From a pine tree that is 14 ins. diameter at the height of a man's shoulder, from 3 to 5 pole ties may be made. The ties are hewed 8 to $8\frac{1}{2}$ ft. long, 6 ins. thick, with two hewed faces 8 ins. wide, and the bark on the sides is peeled with a tie peeler. A skillful man can cut and make 40 to 50 of these ties per day.

Cost of Timber Trestles and Culverts.—Mr. William Barclay Parsons gives the following data on the cost of railway trestles built in 1890, in the northwestern part of Pennsylvania, in a wooded mountainous district. The timber was hemlock and most of it was sawed, but about one-seventh, or 14%, of the timbers were hewed. Bents were 12 ft. apart, with 12 × 12-in. posts, caps and sills; stringers were 12 × 18-in. Bents were braced with 2 × 12's. Trestles were made up to 28 ft. in height. All members were fastened with drift bolts. About 102 M were used, of which 14 M were hewed from timber alongside. The average cost of the sawed timber was $7.50 per M. The cost of labor for framing and erecting (including the 14% hewed work) was $9.50 per M.

In Engineering News, Oct. 6, 1892, p. 326, Mr. Emile Low gives the itemized cost of a narrow gage (3 ft.) railway from Castle Shannon, to Finleyville, Pa. The tracklaying cost less than $200 per mile. There were 15 M of sawed timber culverts, the labor on which cost $8 per M; and 35 M of wooden bridges, the labor on which also cost $8 per M.

In the section on Pile Driving and Timberwork the reader will find a number of other examples of the cost of trestles, etc.

A Cheap Way of Loading Ties.—In Engineering News, Sept. 18, 1902, the following device for economic handling of ties is described. The device is so simple and so well adapted to handling other materials that the details are here given. It consists of an overhead trolley, traveling on a 4-in. I-beam that serves as a rail. In loading box cars with ties, one end of this I-beam is supported on a light wooden A-frame, 7 ft. high and standing about 15 ft. from the car door; the other end of the I-beam enters the car door, and inside the door it is fastened to two bars (¼ × 3 ins.) that branch, forming a Y with curved branches, so that one trolley can run toward one end of the car, another trolley toward the other end. The trackway in the car is hung from the roof rafters by clamps. From each of the trolleys is suspended, by a chain, an L-shaped tie stirrup for carrying a tie. Two men unload a tie from a truck and place it on the tie-stirrup, one man (one on each trolley) runs the tie into the car, the track having a slight down grade, and one man (one at each end of the car) assists in unloading and piling. The man then takes the trolley off the track and carries it back to the loaders. Thus with a gang of 6 men as much work is done as with 10 men unaided by this device. A gang of 6 men loaded 3,325 large creosoted hewn ties in 9 hrs., no effort being made to make a record. When timed they unloaded a truck of 30 ties into the car in 2 mins. Creosoted ties weigh 200 to 250 lbs. each, and as one man by using a trolley can easily transport them, it is evident that much labor is saved. I would suggest the use of a similar device for handling sacks of cement (2 sacks on a double stirrup), for handling brick, two-man stone, etc.

A Method of Unloading Rails.—An effective method of unloading rails, along a track where new rails are to be put in, is described and illustrated in Engineering News, March 28, 1891. The car is provided with a tail board that hangs down and drags along on the track, forming an inclined plane. A hook on a rope is hooked into a rail, and another hook, on the other end of the rope, is hooked over a tie. As the car moves slowly forward the rail is dragged out. By having two of these ropes and hooks, pulling out two rails at a time, 71 rails were un-

loaded in 25 mins. from a drop end gondola, and 86 rails in 42 mins. from a solid end gondola.

Cost of Tracklaying, M., St. Paul & S. S. M. Ry.—In Engineering News, Nov. 14, 1895, the following data are given, together with illustrations showing the bunk-cars, tie wagons, etc.:

About 263 miles of track were laid in 1892-3 from Valley City across North Dakota. The tracklaying and surfacing were done by the railway company, not by contract. The track was 72-lb. rails laid on 16 ties to the 30-ft. rail. The construction train was made up of 32 cars, the locomotive being in the middle of the train. The next car behind the locomotive was an ordinary flat car loaded with telegraph material; then followed 15 box cars loaded with ties. In front of the locomotive were the following cars, No. 1 being the one farthest front.

No. 1, Pioneer car. This was double deck, containing blacksmith shop, store room, general foreman's office, telegraph office, two sleeping rooms, and three extra berths. In front of the car was a platform carrying extra splice bars, bolts and spikes.

No. 2, store car. This was double deck, and had a store room for provisions and one for clothes, sleeping berths for cooks and a sleeping apartment above.

Nos. 3 and 4, dining and sleeping cars, double deck.

No. 5, kitchen car, single deck.

No. 6, dining and sleeping car, double deck.

No. 7, feed and fuel car, ordinary box car.

No. 8, water car, flat car with a 2,000-gal. tank at each end.

Nos. 9 to 16, flat cars with rails and spikes.

Work commenced at 7 a. m., the teams hauling ties from the five rear cars. The ties were shoved from the car down a tie chute, provided with three rollers, and were loaded into a V-shaped rack on a wagon holding 25 ties. The rails were unloaded onto the ground from both sides of the cars, and the train pulled back out of the way. The rails were loaded onto two "iron cars" and hauled to the end of the track by horses. The iron car gang would "drop" 100 rails (1,500 ft. of track) in half an hour. As soon as a pair was dropped upon the ties, a hook gage was thrown over them, at the forward end, and the horse

pulled the car forward 30 ft. Two more rails were then run out, and so on. The tracklaying force was as follows:

Iron car gang, who dropped rails ($2.25 each)	22
Strappers, who adjusted and bolted splices ($2 each)	6
Spike peddlers ($1.50 each)	2
Tie-spacing gang ($1.50 each)	12
Men lining ties, with rope and stakes ($1.75 each)	2
Men spacing joint ties ($1.75 each)	2
Men leveling grade cut by tie wagons ($1.50 each)	4
Spikers ($2 each)	16
Nippers, holding up end ties for spikers ($1.50 each)	8
Tracklining gang ($1.75 each)	6
Teamsters for tie wagons ($35 per mo. and board)	40
Men unloading ties from cars ($1.75 each)	15
Men unloading rails and fastenings from cars ($1.75 each)	4
Telegraph gang	8
Telegraph operator ($50 per mo.)	1
Drivers of iron car horses	2
Blacksmith ($2.25)	1
Night watchman	1
Cooks ($50 per mo.)	2
Baker, working nights	1
Waiters	5
Storekeeper	1
Total men	161
Foremen ($65 per mo. each)	5
General foreman ($150 per mo.)	1

Note that the teams of horses are not included, but the drivers of the teams are included in the above. The men were boarded for $3.50 a week, and this was deducted from the wages of all except teamsters.

The telegraph gang, consisted of 8 men and 1 foreman. The cedar poles were 25 ft. long, spaced 30 to the mile, set 5 ft. in the ground. The wire was stretched from a reel on a small hand wagon pushed by the men.

This force of 167 men and about 45 pairs of horses averaged 3 miles of track per day. If we consider a pair of horses (not including driver) as equivalent in cost to the wages of one man, and the average wages as being $1.75

per day per man, we have a total daily cost of $371, not including the cost of operating two locomotives. About $405 would apparently cover the daily cost, at which rate the cost of tracklaying was about $135 per mile, including the erecting of the telegraph line, but not including the cost of surfacing the track. On one occasion the above force laid 4 miles in 10 hrs. In dry open country, like North Dakota, this method was faster than working with track machines and no more expensive. In swampy, very hilly or timbered country, the tracklaying machines are especially serviceable.

The track surfacing gangs followed the tracklayers and surfaced the track so as to make a safe roadway and prevent bending of the rails and splices before the ballasting was done. These gangs numbered 40 to 45 men under a foreman and sub-foreman. About 250 men were required, and they went to and from work on hand cars, their boarding cars being located on the sidings which were put in about every 10 miles. It would appear from this statement that the surfacing cost about as much per mile as the tracklaying; bringing the total to $250 per mile.

Cost of Tracklaying, 50-lb. Rails.—The following gang averaged one-mile of track laid per day by contract. The track was not surfaced by this force.

	Per day.
Tie gang:	
1 panel spacer, at $1.50	$1.50
1 tie surfacer, at $1.50	1.50
2 tie liners, at $1.50	3.00
3 tie unloaders, at $1.50	4.50
6 tie spreaders, at $1.50	9.00
1 waterboy, at $1.25	1.25
1 foreman, at $3.00	3.00
Iron gang:	
1 gager, at $2.00	2.00
2 heelers, at $2.00	4.00
2 unloaders, at $2.00	4.00
6 iron men, at $2.00	12.00
1 waterboy, at $1.25	1.25
1 foreman, at $3.00	3.00

	Per day.
Front gang:	
1 tie spacer, at $1.50	1.50
1 spike peddler, at $1.50	1.50
2 nippers, at $1.50	3.00
4 spikers, at $2.00	8.00
5 strappers, at $1.50	7.50
1 waterboy, at $1.25	1.25
1 foreman, at $3.00	3.00
Tie loading gang:	
16 men (4 gangs of 4 each), at $1.50	24.00
1 waterboy, at $1.25	1.25
1 foreman, at $3.00	3.00
Back spiking gang:	
1 tie spacer, at $1.50	1.50
2 spike peddlers, at $1.50	3.00
4 nippers, at $1.50	6.00
8 spikers, at $2.00	16.00
1 waterboy, at $1.25	1.25
1 foreman, at $3.00	3.00
Lining gang:	
5 men, at $1.50	7.50
1 waterboy, at $1.25	1.25
Back filling gang:	
15 men, at $1.50	22.50
1 waterboy, at $1.25	1.25
1 foreman, at $3.00	3.00
Hauling gang:	
18 teamsters, at $1.80	32.40
1 waterboy, at $1.25	1.25
40 mules' feed, at $0.40	16.00
1 wagon master, at $3.00	3.00
General force:	
1 camp boss, teamsters' camp, at $2.25	2.25
1 blacksmith, at $2.25	2.25
2 night watchmen, at $2.25	4.50
1 tool man, at $2.00	2.00
1 bookkeeper, at $4.00	4.00
1 superintendent, at $5.00	5.00
Material train, fuel and wages	24.00
Total per day	$266.90

The force, as above given, can lay 1½ miles of steel track per day, but cannot keep up the back work and average much more than one mile. All ties are full spiked; 15 ties to a 30-ft. rail; 50-lb. steel rails. The ties and steel are delivered to the contractor on cars at the last side track; and side tracks are about 8 miles apart. A material train is made up of 10 tie cars, each holding 135 ties, and 3 steel cars, each holding 60 rails. This train is at the boarding train at 6 a. m., in time to take the force to the front after breakfast. The back-fillers, liners and back-spikers are dropped where work had stopped the day before, and the 10 cars of ties (which are in the rear of the locomotive) are uncoupled far enough back to give the train room to move ahead with the 3 cars of steel (which are in front of the locomotive) as far as the "iron car" upon which 30 rails at a time are loaded and pushed up front. The two unloaders in the iron gang assist in loading the iron car; and, while the rails on the iron car are being laid, they throw off another 30 rails from the flat cars ready to be loaded on the iron car. The 10 cars of ties are brought up as fast as the track will allow, and only enough are unloaded by the tie loaders at one time to keep the wagons busy. At noon the train carries the force back to dinner, the empty flat cars are side tracked, and another train of 10 tie cars and 3 steel cars brought up in time to take the men back after dinner.

In laying the track, the panel spacer with a 30-ft. pole and pick keeps far enough ahead to do duty as the roadmaster. The front gangs of spikers (2 on each rail) spike 3 ties in each panel, always the joint and the 6th and 11th ties, skipping 4 ties each time. Of the 5 strappers, one untrims the plates, leaving plates, nuts and bolts on the joint tie, and the other 4, working 2 on a side, strap up and bolt the joints. Should the back-spikers get behind, they are assisted by the front-spikers. Should the back-fillers get behind, they are reinforced by the tie gangs, and the iron gang and strappers can be putting in the sidings.

Of the teams, 16 are used to haul ties, 1 to pull the iron car, and 1 to haul water to the boarding train. The 16 teams haul 14 loads of 12 ties each per day, making 2,688 ties.

Cost of Tracklaying on the A., T. & S. Fe R. R.—With a well organized force the cost of laying the Arkansas City extension of the A., T. & S. Fe, in 1888, was $292 per mile for a month's work. On the same road the following force laid 2 miles per day:

	Per day.
15 men running iron car, at $1.75	$26.25
2 men unloading iron, at $1.75	3.50
24 men spiking, at $1.75	42.00
8 men strapping, at $1.75	14.00
5 men spacing ties and "squaring" joints, at $1.75	8.75
4 men lining track, at $1.75	7.00
7 men setting "joint and center" ties, at $1.75..	12.25
2 men carrying gages, at $1.75	3.50
2 men distributing spikes, at $1.75..............	3.50
1 man caring for tools, at $1.75	1.75
42 men bedding ties, at $1.40	58.80
12 men ("nippers"), at $1.40	16.80
18 men handling ties, at $1.40	25.20
2 men stretching tie line, at $1.40	2.80
4 men carrying water, at $1.40	5.60
1 general foreman	3.33
1 foreman iron car............................	2.50
1 foreman tie bedding	2.50
1 foreman handling ties	2.50
1 foreman track lining	2.50
1 foreman spiking gang	2.00
10 extra men, at $1.40	14.00
22 teams hauling ties, at $3.50	77.00
1 team hauling iron car, at $3.50..............	3.50
Total cost of laying 2 miles	$341.53

In addition to this the surfacing of 2 miles of track per day cost as follows:

80 shovelers, at $1.40	$112.20
2 "back-bolters," at $1.75	3.50
1 foreman raising track	2.00
1 foreman	2.50
Total cost of surfacing 2 miles	$120.20

Summary.

Laying 2 miles	$341.53
Surfacing 2 miles	120.20
Superintendent of tracklaying	5.00
Timekeeper	3.00
Train and engine crews	15.04
Engineering	10.97
Cost of labor only for 2 miles	$495.74

This is practically $250 per mile of track. It does not include the cost of supplying and distributing of ballast by train. On the Larned branch 15 miles were laid in 7 days, but under the favorable circumstance of light grades, light work, light earth for ballast, and roadbed in first-class condition. Under ordinary conditions the cost of laying and surfacing should never exceed $350 per mile.

Cost of Tracklaying, A., T. & S. F. Ry.—In Engineering News, Nov. 8, 1900, the following data are given:

Some rapid work was done (1899) in the extension of the A., T. & S. F. Ry. from Stockton, Cal., to Port Richmond. The rails were laid with broken joints, 17 ties per rail. One stretch of 11 miles (62½-lb. rails) was laid at the rate of 2,846 ft. per day, with a force of 45 men, on level grade. Another stretch of 17 miles (75-lb. rails) was laid at the rate of 3,500 ft. per day, with 48 men, on a descending grade of 1%, with curves at intervals of ½ mile. The best day's work, on the level grade, was 5,400 ft., with 57 men. The force was as follows:

Foreman	1	Spike peddler	1
Sub-Foremen	3	Spacing ties	2
Strappers	4	Spacing rails	2
Iron car men	10	Back bolting	2
Spikers	8	Tie carriers	10
Nippers	4	Picking up materials	1
Tie line man	1		
Lining ties	2	Total	52
Tie plater	1		

Record of Rapid Construction on the C. P. Ry.—In the Jour. Assoc. Eng. Soc., 1884, p. 150, Mr. E. T. Ab-

bott gives a brief account of the rapid construction of 500 miles of single track road across the prairies from Brandon (132 miles west of Winnipeg). Ground was broken May 28, 1882, and continued to Dec. 31. In 182 working days, including stormy ones, with a force of about 5,000 men and 1,700 teams, the contractors did the following:

6,104,000 cu. yds. earth excav., 2,394 M timber in bridges and culverts, 85,700 lin. ft. piling, and 435 miles of tracklaying. The track was all laid from one end, and in no case were the rails hauled ahead by team. Two iron cars were used, the empty one on its return being turned up beside the track to let the loaded one by. The tracklaying crew was equal to 4 miles a day. In the month of August, 92 miles of track were laid. The grading forces were scattered along 150 miles ahead of the track. Sidings 1,500 ft. long were graded 7 miles apart.

Cost of Tracklaying, P., S. & N. R. R.—In Engineering News, Nov. 22, 1900, p. 356, Mr. G. C. Woollard gives the following on tracklaying on the Pittsburg, Shawmut & Northern R. R. The length of track laid was 8 miles. With a gang of 46 men and 3 foremen the average day's work was 2,870 ft. of track laid; the best day's work was 3,290 ft. There were 18 men and a foreman in the tracklaying gang; 17 men and a foreman in the supply gang; 11 men and a foreman in the back-tieing gang. Beside these men there were a locomotive engineer, fireman, conductor and a brakeman. No teams were used. Trucks passed one another by raising one truck to a vertical position on the cross-ties and then allowing it to drop back to an oblique position, keeping it from turning over by means of a prop while the loaded truck passed. There were 18 oak ties to a rail, and rails were 85-lb. All the work was on a 2% down grade, which facilitated delivery of materials by gravity.

Cost of Tracklaying Under Traffic.—During a traffic of one train per hour, in winter, the cost of taking up old rails, unloading and placing new rails on a single track, was $140 per mile. The wages of common laborers were $1.25 per 10 hrs.

Cost of Tracklaying With Machines.—Tracklaying machines do not lay the track, but merely facilitate the de-

livery of ties and rails on a series of rollers from the cars to the tracklaying gang of men. In rugged or swampy country a tracklaying machine is especially economic, because the ties cannot be easily delivered by teams.

With a Holman tracklaying machine, 120 miles of the Washington County Ry. (Maine) were laid in 1899. The best day's work was 2 miles laid in 9 hrs. with 110 men.

On the Burlington & Missouri River Ry., with a gang of 85 men and a Holman machine, 1½ miles per day were laid at a cost of $100 per mile. The rails were 65-lb. rails, with 18 ties to a rail. Curves of 1° to 16° were laid. Equally good work was done with the Harris tracklaying machine.

On the Chicago, Rock Island & Pacific Ry., 1,300 miles of track were laid with a Harris machine in 1886 and 1887. The average cost of laying 2 miles per day was as follows:

1 general foreman	$5.00
2 assistant foremen, at $3	6.00
109 laborers, at $2	218.00
1 engine and train crew	20.00
Total for 2 miles	$249.00

To this must be added $10 per mile for preparatory work in transferring material to cars in the yard, and $5 per mile royalty for use of the Harris machine, bringing the total to $140 per mile.

The Harris machine is said to be quicker than the Holman, where long stretches are to be laid; but the Holman is more economical for short stretches or where delays are frequent, as the gang is smaller.

Another machine that has been extensively used is the Roberts.

For further information consult Tratman's "Railway Track and Track Work."

Cost of Laying a Narrow Gage Track.—Where ties and rails are dumped along in small piles, and where no grading has to be done, a gang of 3 men will average 210 ft. of track laid in 10 hrs. This applies to a light 3-ft.

gage track made of 30-lb. rails on 6 × 6-in. ties, 5 ft. long, spaced 3-ft. centers. With wages at 15 cts. per hr., the labor cost is practically 2 cts. per ft. of track, or $100 per mile, after the materials are delivered.

Cost of Gravel Ballasting Single Track.—About 30 miles of single track railroad were ballasted with gravel sufficient to raise the ties 8 ins. Ties had 10-in. face, were 8½ ft. long, and there were 16 ties to a 30-ft. rail. A 2½-yd. steam shovel was used to load flat cars. About 4 ft. of earth had to be stripped off the gravel pit. The gravel was hauled by two trains of 35 apron flat cars each, each car holding 6 to 7 cu. yds. Two locomofives were used to haul these trains and one locomotive in the pit to spot cars. The cars were unloaded with a plow, and it will be noticed that the damage to the cars caused by the plow was very high. The cost to the railway company per cubic yard of ballast in place was as follows:

	Cts. per cu. yd.
Pit rent	1½
Loading, hauling and dumping	15½
Repairs to cars	5
Shoveling and tamping	8
Total per cu. yd.	30

Common laborers were paid $1.25 per 10 hrs.

Cost of Ballasting, Using Dump Cars.—The Goodwin steel car is largely used by contractors, and railway companies. for ballasting and for dumping earth and rock on standard gage tracks. Its dimensions are 36 ft. long, 9 ft. ¼-in. height above rails, and it weighs 47,500 lbs. Its capacity is 40 cu. yds., or 80,000 lbs. A train of cars can be dumped at one time all together, or one at a time, by one man operating a compressed air valve, or they can be dumped by hand. The car is so designed that its load may be placed between the rails; on either side of the track, or on both sides, or in any combination of ways desired. In grading and ballasting 22 miles of track with 30,000 cu. yds. of gravel, during the winter of 1904-5, an average train of 8 40-cu. yd. Goodwin cars was used, the

average haul being 14½ miles. The gravel came from the pit quite wet, but required little or no spreading as plows and scrapers are not needed when these cars are used.

In Engineering News, Feb. 17, 1898, Mr. W. B. Stimson, Supt. Grand Rapids & Indiana Ry., gives the following data on the loading and hauling of gravel for ballast:

Rodger ballast cars were used, working two trains of 25 cars per train. Sixteen miles of track were ballasted with 1,039 car loads, or 20,800 cu. yds. of gravel, the average haul being 7 miles. The cost was as follows for the 16 miles:

Two train crews, 12 days each	$175.00
Locomotives, enginemen and watchmen	199.25
Fuel for locomotives	254.10
Telegraph operator	15.50
Pit foreman	28.84
Pitmen	100.35
Steam shovel, including rent of shovel, fuel and wages	323.52
Total, at 5.3 cts. per cu. yd.	$1,096.56

In addition to this it cost 6.7 cts. per cu. yd. to spread and tamp the gravel in the track, each laborer averaging 75 ft. of track per day. Including in the expense of 5.3 cts. per cu. yd., is the cost of moving the two trains and the steam shovel 166 miles to the pit, and half a day's time setting up the shovel and getting ready to work; so that the actual working time of the shovel was only 10½ days, making an average of 2,000 cu. yds. loaded per day of 12 hrs. The depth of the face at which the shovel worked was only 8 ft.

The Rodger ballast car is 8 ft. 9 ins. × 34 ft. over sills, weighs 28,000 lbs. and its capacity is 60,000 lbs., or 20 cu. yds. of gravel heaped measure. The car is hopper bottomed, with plows and scrapers for spreading the ballast. One car is dumped at a time and fills about 80 ft. of track.

Cost of Railway Lines.—In Engineering Magazine, Dec., 1895, Mr. J. F. Wallace gives the following estimates of

the average cost per mile of single track railway lines in the United States:

Class of Railway.	A	B	C
Right of Way	$1,000	$1,500	$2,000
Proportionate expense of terminals	500	1,500	5,000
Bridges and culverts	1,500	2,500	4,000
Grading	3,000	6,000	12,000
Track laid	6,000	6,500	7,000
Ballast (rock)	......	2,500	3,000
Fencing	300	400	400
Telegraph	200	250	250
Water supply and stations	500	800	1,200
Engineering	400	500	700
General and legal expenses	200	400	600
Equipment, cars and locomotives	1,500	2,500	4,000
Total	$15,100	$25,350	$40,150

Class "A" is a branch line, 2 passenger and 4 daily freight trains.

Class "B" is a secondary line, connecting small cities.

Class "C" is a trunk line, 90-lb. rails.

Mr. A. Pew, in Trans. Am. Soc. C. E., Vol. 23, in a paper entitled "The Cheapest Railway in the World," gives the following as the cost of a 19-mile railway in Georgia:

Cost per mile of road and track	$3,440
Cost per mile for equipment	1,000

The roadbed was only 10 ft. wide in fills and 14 ft. in cuts, and the excavation averaged 4,000 cu. yds. per mile. The excavation cost only 9 cts. per cu. yd., wages of laborers being $1 per 10-hr. day. The ties cost only 10 cts. each, and 45-lb. rails were used.

I would add that often the country is such that much less than 4,000 cu. yds. of excavation per mile will suffice. Ordinarily, however, the excavation will average 10,000 cu. yds. per mile, which may be done at a contract price of 20 to 30 cts. per cu. yd. of earth, when wages of laborers are $1.50 a day.

Cost of a Logging Railway.—Mr. William Barclay Parsons, in Trans. Am. Soc. C. E., Vol. 25, p. 119, briefly describes the location and construction of 7 miles of standard gage logging railroad built in Northwestern Pennsylvania in 1890. The maximum curve was 18°, and the ruling grade, 3.3%. The country was heavily wooded with hemlock and very rough; clearing and grubbing costing

$50 to $60 an acre for a right of way 50 ft. wide. Cuts were 16 ft. wide and fills 12 ft. Log culverts were used under banks 10 ft. or less in height. The excavation averaged nearly 11,000 cu. yds. per mile, of which 7.6% was rock, 11% loose rock, 35.2% tough clay (1 pick to 1 shovel), and 46.2% earth, most of which was heavy soil. The clearing and grubbing, log culverts and excavation when charged up to the excavation cost 46½ cts. per cu. yd., or about $5,000 per mile. (The excavation alone probably cost about 40 cts. per cu. yd. The toughness of the earth and the presence of roots made the excavation expensive. Wages were probably $1.25 per 10-hr. day.) The cost of one mile of finished road on the heaviest part of the line was as follows:

62.86 tons of 40-lb. rails, at $33	$2,074.38
352 joints complete, at 0.55 cts.	193.60
6,200 lbs. spikes, at 2¼ cts.	139.50
3,000 cross ties, at 0.15 cts.	450.00
Freight on materials	159.00
Tracklaying	400.00
Grading	5,026.89
Trestles (at $17 per M in place)	250.45
Surveys, inspection, etc.	400.00
Total per mile	$9,093.82

Cost of Electric Railways.—In the Street Railway Journal, March 3, 1900, p. 237, Mr. John P. Brooks gives the following as the cost of a single track line built (1899) in Denver, Colo.:

	Per mile.
94½ long tons of 60-lb. T-rails, at $23.50	$2,220.75
360 pairs of 60-lb. angles, at 40 cts.	144.00
1,080 lbs. track bolts, at 2¾ cts.	29.70
32 kegs railway spikes, at $4.50	144.00
360 copper or plate bonds, at 25 cts	90.00
2,000 ft. B. M. plank for culverts	42.00
2,640 Texas ties, at 50 cts.	1,320.00
180 ft. of curve and guard rails, at $1	180.00
Hauling ties and rails	130.00
Laying 1 mile of track	550.00
1 mile No. 0 trolley wire	325.00

	Per mile.
88 cedar poles in place and painted, at $4.25......	$374.00
Overhead work incidentals, including hangers, insulators and ratchets ($60); span wire ($40); and labor ($50)	150.00
2,000 cu. yds. excavation for track trench, at 25 cts..	500.00
	$6,199.45
Add 5% for engineering	300.55
	$6,500.00
Add 2 switches, at $250	500.00
Total per mile	$7,000.00

It is apparent that this line was not laid in a paved street. It will be noticed also that the price of rails, etc., was lower then than now (1905). The cost of power plant and buildings is not included, but may be estimated at $15,000 for a suburban line 5 miles long.

Where paving of streets must be done, use the data given in the section on Roads and Pavements.

In the Street Railway Journal, April 4, 1903, Mr. Ernest Gozenbach has an article describing a first-class, third-rail suburban line, 62½ miles long. Including switches and sidings, the number of miles of single track is actually 66. Of the 62½ miles, 6½ miles are laid in city streets.

Excavation and embankment	$ 96,000
Bridges, abutments and culverts	91,050
Two overhead railway crossings	64,000
Ties, 2,640 per mile, at 55 cts.	96,250
Ballast, 2,200 cu. yds., per mile, at 80 cts..........	116,000
Rails, 70-lb. per yd., at $31 per ton delivered......	225,000
Joints, spikes and bolts for 60-ft. rails	29,500
Labor on track, 56 miles, at $600	33,600
Labor in street track, 6½ miles, at $1,800..........	11,700
Farm and highway crossings	9,500
Wire fences, 24,000 rods, at 73 cts................	17,500
Switches, special work, etc.	21,000
Bonds, 24,000, at 61 cts. in place.................	14,650
Cross bonds and special bonding, at switches......	2,000
Third rail, 70-lb. per yd., 56 miles, at $36 ton......	131,000

Insulators, spikes and bolts, at 62 cts. in place....	18,000
Joint plates, bolts and labor laying rail	9,800
Bonds, 15,000, at 73 cts. in place..................	10,950
Crossings and crossing cables	13,500
Trolley in streets, single-track span construction..	24,000
Power station, 150 KW., at $120 per KW.........	180,000
Power station building, at $11 per KW..........	16,500
Transmission line, 55 miles, at $1,400.............	77,000
Sub-station, freight and depot buildings..........	24,500
Sub-station, railway apparatus	65,000
Batteries	80,000
Telephone line	9,000
Block-signal system	35,000
Stations and platforms	5,250
Switch and platform-lighting circuit	4,000
General office building	8,000
Car shops, shop tools, etc.	24,000
Car bodies and locomotive body	49,000
Trucks and air brakes	27,500
Electric car equipment	76,000
Lighting and power apparatus and supply systems	70,000
Accidents, contingencies and insurance, 5%........	89,000
Administration, superintendence, office expenses, engineering, etc. 5%	89,000
Total, at $29,750 per mile	$1,963,750

This estimate does not include allowance for right of way and legal expense.

Cost of Erecting Trolley Poles.—A gang of 4 men digging holes and 6 men raising poles averaged 36 poles set per 10-hr. day, or 50 cts. per pole. In digging holes 24 ins. diam. and 5 ft. deep for telegraph poles, using a crowbar and "spoon" shovel, a man will dig only 3 holes a day in stiff clay, and 7 holes in average earth.

SECTION XII.

COST OF BRIDGE ERECTION AND PAINTING.

The Weight of Steel Bridges.—The following formulas, taken from Johnson's "Modern Framed Structures," give the weight of steel in trusses and floor-beams of highway and railway bridges.

For a highway bridge with a roadway 16 ft. wide, designed to carry 100 lbs. live load per sq. ft., use the following formula:

$$w = 2\,l + 50.$$

w = weight in lbs. per linear foot of bridge.
l = span in feet.

For bridges of less or greater width of roadway than 16 ft., subtract or add 15 lbs. per lin. ft. for each 2 ft. change in width.

For railroad bridges designed according to Cooper's E-50 loading, the weight of steel per lin. ft. of bridge is as follows:

For deck plate girders,

$$w = 12\,l + 150.$$

For through plate girders with beams and stringers,

$$w = 12\,l + 500.$$

For truss bridges,

$$w = 7\,l + 650.$$

Estimating Cost of Bridge Erection.—The cost of erecting steel bridges should be separated into two main items: (1) cost of falsework, and (2) cost of erecting the steel. Usually, however, engineers who have published cost data have unfortunately lumped these two items together.

The cost of falsework for any given bridge, and of a

traveler of given design can be estimated from the data given in the section on Piling and Timberwork.

The labor cost of erecting the steel trusses should seldom exceed ¾ ct. per lb., wages being $3 a day for bridgemen. Examples of the cost of steel erection work will be found in the section on Building Construction, and in the next paragraph.

Cost of Bridge and Viaduct Erection.—Mr. Henry W. Hodges gives the following in "Polytechnic," 1904:

The steel frames of modern office buildings are usually erected by derricks high enough to erect two or three floors without shifting. The cost of erecting and riveting the steel is $10 to $15 per ton. The trusses of small roofs can be erected cheaply by the use of one or two gin poles.

Plate girders for bridges up to 80-ft. span, and in some cases up to 120-ft., are usually shipped as single pieces. Short girders are skidded flat into position from the car and then turned on edge. Long girders may be lifted from the cars by gallows frames and lowered to position. The cost of erecting plate girders is 0.5 to 1 ct. per lb.

Long span bridge trusses are usually erected on falsework consisting of pile bents and, if high, framed timber bents on top of the piles. It costs about $15 per M to build the timber falsework, exclusive of the cost of the timber. The cost of erecting steel pin-connected bridges is 0.7 to 1.2 cts. per lb.

Draw bridges (swing) are generally erected on the pile fender or guard pier. As this fender is permanent and paid for by the owner, the cost of erecting draw bridges would be less than fixed spans were it not for the extra cost of erecting the turn table. The cost of erecting draw spans varies from 1 to 1.2 cts. per lb.

Viaducts are usually erected by the use of an overhang traveler. The Pecos Viaduct (Eng. News, Jan. 5, 1893) is 2,180 ft. long, 321 ft. high, and has 23 supporting towers. The traveler had an overhang of 126 ft., and no falsework was used. The viaduct weighs 1,820 tons, and was erected by a force of 60 men in 118 working days. The cost of erection was 0.8 ct. per lb., of $16 per ton.

Cost of Erecting Steel in N. Y. Subway.—The cost

of erecting the steel posts and girders in the N. Y. subway was as follows on one section where 4,300 tons were erected:

	Per ton.
Labor trucking	$1.47
Labor placing and riveting	11.68
Labor painting	0.90
Materials for painting	0.70
Materials for placing and riveting	0.90
Power	0.30
Total	$15.95

Iron workers were paid $4 for 8 hrs.; iron foremen, $5; painters, $2. There was 1 foreman to every 10 men.

The contract price for erecting and painting was $13 a ton, so that money was lost by the contractor on this work. The men worked under difficulties, and with little energy.

Cost of Pneumatic Riveting.—Mr. A. B. Manning gives the following data:

One 12-HP. gasoline driven air compressor (Fairbanks, Morse & Co.); two galvanized iron water tanks; one galvanized iron gasoline tank; one large main reservoir; one small auxiliary reservoir; hose and fittings; cost mounted on car $1,073. Operating at 90 lbs. pressure this compressor furnished air for 3 pneumatic hammers, 2 drills, 2 rivet forges, and 1 blacksmith forge, all working at one time. The 3 hammers and the 2 drills cost (in 1899) $627. The cost of repairs for 16 months averaged $3 per month on this $1,700 plant. The cost of operating was as follows per day:

15 gals. gasoline, at 11.2 cts.	$1.68
Oil, waste, etc.	0.12
Depreciation (estimated on 20% basis, for 313 days)	1.09
Repairs	0.11
Total per day	$3.00

On the basis of running 3 rivet hammers, this is $1 per hammer for power.

Power for one hammer per day	$1.00
Oil for one hammer per day	0.12
2 men driving rivets, at $2.40	4.80
1 man heating rivets	2.20
Total for one hammer per day	$8.12

A pneumatic riveter on bridge work averages 500 rivets per 10-hr. day for $8.12, or $1.62 per hundred rivets. On one day 700 rivets were driven, by using an additional man to take out fitting-up bolts, etc. The above costs are based upon the erection of 22 bridge spans, aggregating 2,455 lin. ft. and 80,065 rivets.

The cost of riveting by hand is as follows:

2 men, at $2.40	$4.80
2 men, at $2.20	4.40
Total per gang per day	$9.20

Such a gang averages 250 rivets per day, which is equivalent to $3.68 per hundred rivets.

Mr. F. S. Edinger states that with a 12-HP. gasoline driven compressor and an 80 cu. ft. air receiver, five long-stroke hammers were operated at one time without reducing the air pressure below 75 lbs. •The five hammers when driving 50 rivets (⅞-in. diam.) per minute are using air only about 5% of the time. The same compressor will run 2 hammers and 2 drills at one time. The drills use more air than the hammers as they run uninterruptedly. The drills can be used for boring timber by inserting an auger in place of a drill; but the speed is not high enough for wood boring. Two men and a heater form a riveting gang and they drive twice as many rivets as three men and a heater drive by hand. The cost of fitting up and riveting on new steel bridges (all rivets ⅞-in.) was 35 to 40% less than if the work had been done by hand, and the work was done better.

Cost of Tearing Down a Small Bridge.—A small highway bridge of 35-ft. span, and roadway 25 ft. wide, contained 10 tons of iron in the trusses and 4,650 ft. B. M. in the flooring. The flooring was 3-in. oak plank laid on

3 × 12-in. stringers spaced 2 ft. apart, and two 8 × 14-in. stringers under an electric car track. It took 6 men and 1 foreman 3 days to tear down and store the bridge, at a cost of $36.

A wooden footbridge, 6 ft. wide and 100 ft. long over a creek, contained 4,000 ft. B. M. It took 8 men and a team 3 hrs. to tear down and remove this structure, which was essentially a light temporary trestle floored with 3-in. plank. The cost was $1 per M for this tearing down. The same gang had originally erected this structure at a cost of $3.75 per M.

Cost of Moving a 65-ft. Bridge and New Abutments.—A steel highway pony truss bridge of 65-ft. span and 16-ft. roadway had been erected upon timber pile abutments that had rotted badly. New abutments were built adjoining the old abutments, by driving 12 iron piles for each abutment and its wing walls. These piles were of old steel rails 30 ft. long, and were driven 20 ft. deep. A small pile driver operated by 5 men and 1 horse averaged 8 piles per 10-hr. day, for 3 days. Then 1 day was spent in building a falsework, and 2 more days raising and shifting the bridge from its old abutments to the new. The cost of pile driving was $30, or $1.25 per pile. The cost of building the falsework was $10, and the cost of moving the bridge was $20.

Cost of Paint.—In Engineering News, June 6, 1895, Mr. Walter G. Berg, Chief Engineer of the Lehigh Valley R. R., has an excellent article on painting iron railway bridges, and the paints to select. He gives the following as to the cost of paints:

Oxide of Iron.	
6¼ lbs. oxide of iron, at 1 ct.	$0.06
5/6 gal. (6¼ lbs.) raw linseed oil, at 56 cts.	0.47
Cost of 1 gal. of paint	$0.53
Red Lead.	
20 lbs. red lead, at 5 cts.	$1.00
¾ gal. (5½ lbs.) raw linseed oil, at 56 cts.	0.42
Cost of 1 gal. of paint	$1.42

Graphite.

3¾ lbs. graphite paste, at 12 cts.	$0.45
¾ gal. boiled linseed oil, at 59 cts................	0.45
Cost of 1 gal. of paint	$0.90

Painting Data.—A gallon of iron oxide paint will cover 400 sq. ft. of wood surface, or 500 sq. ft. of iron surface, first coat. It requires about two-thirds as much paint for the second coat as for the first; and half as much paint for the third coat as for the first. Further data will be found on page 558.

A man, working 9 hrs. can paint (one coat) 2,000 sq. ft. of tin roof, or 1,000 sq. ft. of frame house, or 300 sq. ft. of bridge trusses. The shifting of scaffolds on house work accounts for the decreased time; and the smaller area of the surfaces of bridge trusses makes the work slower in bridge painting.

Weight and Surface Area of Steel Bridges.—In Engineering News, Feb. 6, 1896, Mr. C. E. Fowler, then Chief Engineer Youngstown Bridge Co., gives a table of the weights of iron highway and single track bridge trusses, and the corresponding areas of metal requiring painting, as determined "by actual calculation in a large number of cases." I find by a study of the tables that they can be very simply expressed in rules or formulas, as follows: For a highway bridge divide the weight of metal in pounds by 7 to get the area of metal surface in square feet. This applies to highway bridges 16 ft. wide, calculated for a floor load of 90 lbs. per sq. ft., for all spans from 40 to 300 ft. For a single track railway bridge, divide the weight of metal in pounds by 12 to get the area of metal surface in square feet.

The weight in pounds of metal in a highway bridge is found by adding 50 to 2 times the span in feet and multiplying this sum by the span in feet. Expressed in a formula this rule is $w = l\ (2\ l + 50)$.

The weight in pounds of metal in a single track railway bridge is found by adding 400 to 4.8 times the span in feet and multiplying this sum by the span in feet. $w = l\ (4.8\ l + 400)$.

The weights of railway spans are considerably greater now than in 1895, but the foregoing facts will be of value especially for highway bridges. Mr. Fowler gives the following estimates of the area of metal surface covered by different kinds of paints:

	Area in sq. ft. covered by one gallon.	
	First coat.	Second coat.
Oxide of iron	500	700
Red lead	700	1,000
White lead	500	700
Graphite	500	700
Asphalt	300	500
Carbonizing coating	1,000	1,500

He adds that manufacturers give too large areas covered by their paints; and that the above figures apply only to the best, finely ground pigments.

Cost of Painting a Tin Roof.—In Engineering News, April 23, 1896, Mr. J. M. Braxton gives the following:

An old tin roof was showing rust spots, most of the paint being worn off. The tin was first rubbed with palmetto brushes and then swept clean. The area painted was 151,000 sq. ft., requiring 563 gals. of paint for two coats, or 267 sq. ft. per gallon for the two coats. The paint was:

396 gallons raw linseed oil.
35 lbs. dryer.
2,120 lbs. dry oxide of iron.

This mixture yielded 563 gals. of paint. Each man averaged 1,920 sq. ft., or 220 sq. yds. per day of 9 hrs. painted with one coat. It took 158 man-days to paint the roof, not including foreman's time.

Cost of Painting a Howe Truss Bridge.—The bridge was painted with two coats of paint costing $1 per gallon. One gallon covered 133 sq. ft., two coats thick, and a painter averaged 166 sq. ft., two coats thick, per 10 hrs., or 332 sq. ft. of one coat per day. The cost was, therefore, as follows:

	Cts. per sq. ft.	Cts. per sq. yd.
Paint, two coats	0.75	6.8
Labor painting, two coats (17½ cts. per hr.)	1.15	10.3
Total	1.90	17.1

Cost of Painting 6 R. R. Bridges.—Three spans pin-

connected Pratt truss bridges, each 145 ft. long, 14 ft. wide and 20½ ft. high, were painted with one coat at a cost of $48 per span for labor. One span required 35 gals. of asphaltum paint costing 65 cts. per gal. The other spans received 27 gals. of carbon paint each, at $1.50 per gallon.

A riveted Pratt truss bridge, 94 ft. long, 14 ft. wide and 20 ft. high was given one coat of black carbon paint, 23 gals., at $1.50 per gal. The labor was $40.

A double-intersection riveted lattice truss bridge, 96 ft. long, 14 ft. wide and 20 ft. high, was repainted with one coat of carbon paint, 26 gals., at $1.50 per gal. The labor cost $46.

A single intersection lattice truss highway bridge (20-ft. roadway and two 8-ft. sidewalks), 106 ft. long, was painted with one coat of black carbon paint, 35 gals., at $1.25 per gal. The labor cost $59.

Cost of Painting 6 R. R. Bridges and 2 Viaducts.— Mr. O. E. Selby, in Trans. Am. Soc. C. E., 1897, has a paper on the cost of painting the Louisville and Jeffersonville Bridge across the Ohio River. The work was begun June 3, and finished Aug. 7, 1895. There was practically no traffic over the bridge during the work, which, of course, lessened the cost of painting; and the iron being new required no great amount of cleaning. The force averaged about 50 men with 1 foreman, 1 assistant foreman and 1 timekeeper. The men were mostly ordinary bridge men, erectors and carpenters, and were paid $2 a day of 10 hrs. Some few men painting sidewalk railings and other parts not hazardous were paid $1.50 a day. The paint was oxide of iron, and was used just as it came from the barrel, except for a little occasional thinning, equivalent to about ½ gal. per bbl. of paint. The cost of the paint was 67 cts. per gal. The best results were obtained with flat brushes costing $7.50 per doz., of which 19 doz. were used; 4 doz. steel brushes and 13 doz. whisk brooms were used for cleaning the iron. The total cost of the work was: Paint, $3,769; labor, $4,427; equipment, $301; accident insurance, $200; total, $8,697 distributed as follows:

Jeffersonville Approach and Span No. 1 (4,271 ft. long; 1,762 tons).

	Per ton.
0.62 gallon iron oxide paint	$0.42
Labor, $2 per 10 hrs.	0.51
Total per ton of 2,000 lbs.	$0.93
Total per lin. ft.	$0.38

This Jeffersonville approach is a viaduct having an average height of 40 ft. and a length of 4,063 ft., all single track, except 1,000 ft., which is double track. Span No. 1 is single track, 209 ft. c. to c. The Jeffersonville approach had previously been painted with one coat in Oct., 1892. The work of which costs are above given consisted in going over the viaduct, cleaning and painting all spots where rust had formed; then after this had dried the whole viaduct was given one coat.

Louisville Approach (2,585 ft. long; 1,012 tons).

	Per ton.
0.90 gallon paint, first coat	$0.61
0.58 gallon paint, second coat	0.39
Labor on first coat	0.72
Labor on second coat	0.38
Total per ton	$2.10
Total per lin. ft	$0.82

This Louisville approach is 2,585 ft. long, single track, and has an average height of 45 ft. It had been erected a year before it was painted, and had never been painted before. It received two coats throughout.

Bridge spans Nos. 5 and 6 (each 338 ft. c. to c.; total weight 665 tons).

	Per ton.
0.66 gallon paint, first coat	$0.44
0.44 gallon paint, second coat	0.30
Labor on first coat	0.47
Labor on second coat	0.35
Total per ton of 2,000 lbs.	$1.56
Total per lin. ft.	$1.53

Bridge spans Nos. 2, 3 and 4 (each span 546½ ft. c. to. c.; total, 2,768 tons).	Per ton.
0.50 gallon paint, first coat	$0.33
0.32 gallon paint, second coat	0.22
Labor on first coat	0.32
Labor on second coat	0.22
Total per ton of 2,000 lbs.	$1.09
Total per lin. ft.	$1.84

All these bridge spans were single track, erected about a year before they were painted. All the iron had had a shop coat of linseed oil. All the spans were given two coats of paint throughout, except the inside of the top chords and end posts which received only one coat, as it was believed that this one coat in such a protected location would outlast the two coats on exposed work.

Spans Nos. 5 and 6 were erected in the latter part of 1893, while the other and longer spans were erected a year later, so that the rustier condition of Nos. 5 and 6 may account for their taking more paint.

The labor cost of painting 5,700 lin. ft. of sidewalk railings was $390, or $6.85 per 100 ft. This does not include the cost of the paint, which was a small item. Half of this railing was a lattice railing 4 ft. high; the other half was a gas pipe railing consisting of two lines of 1¼-in. gas pipe.

Cost of Painting 50 Plate Girder Bridges.—Mr. W. J. Wilgus gives the following data on the cost of repainting 33 steel bridges on the Rome, Watertown & Ogdensburg R. R. in 1896-8. The bridges were originally painted with two coats of "patent paint" that had failed within a year. The following costs include cleaning with wire brushes, and repainting with one coat of asphaltum-varnish paint made of 4 lbs. lampblack ground in pure raw linseed oil, ⅞ gal. genuine asphaltum varnish, ¼ gal. pure boiled linseed oil, and ¼ gal. drying japan. This paint cost 60 to 80 cts. per gal., and 1 gal. covered 350 sq. ft. Labor cost $2 a day.

The calculation of the exposed areas of many of the plate girder bridges showed that there were 100 sq. ft. for every ton of 2,000 lbs.

Cost of painting 50 plate girder spans (av. length, 74 ft.; total weight, 1,884 short tons).

	Per ton.
0.30 gal. paint	$0.175
Labor cleaning and painting	0.340
Total per ton	$0.515

Cost of painting 5 truss spans (av. length, 155 ft.; total weight, 638 tons).

	Per ton.
0.39 gal. paint	$0.235
Labor cleaning and painting	0.490
Total per ton	$0.725

Cost of painting 11 spans of a viaduct (total length, 706 ft.; height, 88 ft.; weight, 342 tons).

	Per ton.
0.48 gal. paint	$0.39
Labor cleaning and painting	0.60
Total per ton	$0.99

Cost of Cleaning and Painting 10 Bridges.—Mr. E. D. Graves gives the following data on the painting of light double triangular trusses in bridge spans from 80 to 136 ft., the total length being 1,000 ft. painted in the summer of 1897. The steel work had received one shop coat of iron oxide paint, and had been in place one year. The greater part of the surfaces was found to be scaled off and rusted. The surfaces were scraped with a steel scraper, or brushed with a steel wire casting-brush. The dust was removed with a whisk broom, and one coat of No. 38 Detroit Graphite paint applied, costing $1.10 per gallon, delivered. The floor beams and bottom chords being most likely to rust, were painted a second coat. The foreman received $3.50 per day, and had 8 to 12 men, at $1.75. These men were mostly laborers, except a few bridge men for the top work. The cost was as follows per ton of 2,000 lbs.:

Cost of first coat:	Per ton.
0.94 gal. first coat on 202 tons	$1.04
Labor cleaning and painting 202 tons	1.44
Total per ton, one coat	$2.48

Cost of second coat (bottom chord and floor beams):

	Per ton.
0.35 gal. second coat on 100 tons	$0.38
Labor painting second coat 100 tons	0.58
Total per ton of bottom chord and beams..	$0.96

The total cost of paint and labor was $598, or nearly 60 cts. per lin. ft. of bridge.

Cost of Painting 48 Bridges and 2 Viaducts.—Mr. C. D. Purdon gives the following data: These bridges were new and painted with two coats of red lead. They had received one coat of oil at the shop.

	Cost per ton.		
	Paint.	Labor.	Total.
Two deck girders, each 54 ft. (34.3 tons).......	$0.80	$1.34	$2.14
Pratt truss, 103 ft. (62.9 tons)..................	0.58	1.45	2.03
Pratt truss, 180 ft. (161.4 tons)................	0.82	1.27	2.09
Six deck girders, each 54 ft. (105.2 tons)......	0.65	1.12	1.77
Iron viaduct; two 64 ft., two 48 ft., and two 32 ft. deck girders (182.4 tons)....	1.40	0.76	2.16
Iron viaduct, eight 64 ft., and seven 32 ft. spans (471 tons).............................	1.00	0.66	1.66
Pratt truss, dbl. track, 150 ft. (228.7 tons)....	0.51	1.17	1.68

The summary of the amount of lead and oil used on the above bridges is as follows:

	Per ton.	
	Lbs. of lead.	Gals. of oil.
Deck girders (139.5 tons).......................	6.08	0.48
Single track trusses (224.3 tons)...............	7.12	0.56
Viaducts (653.3 tons)................	13.80	0.44
Summary of all (1,245.6 tons)..........	10.10	0.42

The cost of cleaning and painting 17 spans over the Arkansas River is as follows: These bridges received two coats of red lead and oil, having been originally painted with iron oxide which was first cleaned off. The cost of cleaning off the old paint is included, and almost equaled the cost of applying the first coat of red lead.

Cost of 9 spans (153 ft.; weight, 810.6 tons):

	Per ton.
First coat:	
7 lbs. red lead	$0.49
Labor	0.58
Second coat:	
2.3 lbs. red lead	0.17
Labor	0.25
Total per ton	$1.49

Cost of 8 spans (three, 253 ft.; four, 162 ft.; one draw, 370 ft.; total weight, 1,451.2 tons):

	Per ton.
First coat:	
6 lbs. red lead	$0.42
Labor	0.54
Second coat:	
1.9 lbs. red lead	0.15
Labor	0.26
Total per ton	$1.37

The average of the above 17 spans was: 6.42 lbs. of lead and 0.23 gal. of oil per ton for the first coat; 2.04 lbs. of lead and 0.074 gal. of oil per ton for the second coat.

The cost of repainting 13 spans with two coats of iron oxide was as follows:

	—Gallons.—		——Cost per ton.——		
	Paint.	Oil.	Paint.	Labor.	Total.
200-ft. deck truss and two 50-ft. girders, dbl. track (475.6 tons)...	128	60	$0.20	$0.62	$0.82
Pony lattice, 92½ ft. (115 tons)....	30	10	0.31	0.33	0.64
Three through spans, 150 ft. and 302 ft. draw span (656.7 tons)...	335	122	0.36	0.63	0.99
Three through spans, 150 ft. (313.3 tons)................................	184	46	0.38	0.54	0.92
Three through spans, 150 ft. (297.6 tons)................................	130	30	0.28	0.54	0.82

These 13 spans had originally been painted with iron oxide which was not cleaned off except at rusted spots.

It will be noted that about ⅓ gal. of oil was used to thin each gallon of paint.

The cost of repainting ten old bridges with one coat of iron oxide was as follows:

	—Gallons.—		——Cost per ton.——		
	Paint.	Oil.	Paint.	Labor.	Total.
Double track truss, 126 ft. (176 tons)	75	25	$0.19	$0.55	$0.74
Through plate girder, 50 ft. (27.6 tons)................................	15	3½	0.34	0.34	0.68
Six spans deck truss, 150 ft. (696.5 tons)................................	280	62	0.25	0.51	0.76
Deck plate girder, 70 ft. (30.4 tons)	12	....	0.20	0.22	0.44
Through plate girder, 47 ft. (24.5 tons)................................	17	....	0.32	0.34	0.66

These 10 spans had been originally painted with iron oxide which was not cleaned off except at rusted spots.

It will be noted that the average of these ten spans is 0.51 gal. of paint and oil per ton, for one coat work.

Cost of Cleaning and Painting 4 Bridges, St. Louis.—Mr. N. W. Eayers gives the following data on painting railway bridges with one coat of carbon paint. This paint was ground especially for the bridge work, and came as "semi-liquid" taking about 1 gal. of oil to 1 gal. of "semi-liquid." It was laid on thick.

The St. Louis Merchants' Bridge is double track, three spans, each of 517½ ft., trusses 75 ft. deep at center. It was erected in 1890, and had had one shop coat and one coat of iron oxide after erection. The metal was very rusty, and the cost of cleaning was quite large, but could not be separated from the cost of painting. The total cost of cleaning and painting these three spans in 1895 was as follows:

493¼ gals. boiled oil, at $0.58	$ 286.08
552½ gals. carbon paint, at $1.25	690.62
Sundry supplies	69.96
48 days' labor, at $2.50	120.00
91.4 days' labor, at $2.25	205.65
444.4 days' labor, at $2.00	888.80
51.5 days' labor, at $1.00	51.50
Total	$2,312.61

The cost per lin. ft. was, therefore, $1.49, and 0.69 gal. of paint, costing 93.3 cts. per gal., was required per lin. ft.

The Ferry St. Bridge is a double track deck span, 126 ft. resting on iron columns. It was cleaned and painted in 1895, at the following cost:

32 gals. boiled oil, at $0.58	$18.56
22 gals. carbon paint, at $1.25	27.50
Labor	97.70
Total, at $1.14 per lin. ft.	$143.76

The Angelica St. Bridge is a through plate girder bridge, 68-ft. span, having a total painted surface of 6,250 sq. ft.,

which required 1 gal. of paint for every $312\frac{1}{2}$ sq. ft. The cost was as follows:

10 gals. boiled oil, at $0.58	$5.80
10 gals. carbon paint, at $1.25	12.50
Labor	22.00
Total, at $0.59 per lin. ft.	$40.30

The Elevated Structure, Merchants' Bridge, consists of steel columns supporting plate girder spans of 28 to 35 ft., carrying a double track railroad. It was erected and painted in 1890, but in 1897 it was badly rusted and was repainted at a contract price of 57 cts. per ft. for 4,075 ft. The actual cost to the contractor was as follows:

Carbon paint and oil, one coat	$ 748.13
Labor for cleaning	657.67
Labor for painting	628.74
Total, exclusive of foreman's time	$2,034.54

The St. Louis (Eads) Bridge was repainted in 1896. It consists of three arched spans of a total length of 1,524 ft., carrying a double track railway on the lower floor and a highway on the upper floor. The floor beams for the highway are the struts for the wind truss. The bridge is 54 ft. wide out to out. The metal was quite rusty, in places, requiring chipping to remove scale, especially the highway floor beams exposed to locomotive smoke. It was painted with one coat. The cost was $0.70 per ton distributed as follows:

675 gals. boiled oil, at $0.35	$ 236.25
650 gals. carbon paint, at $1.25	812.50
Sundry supplies	52.55
Labor, 130 days, at $2.50	325.00
246 days, at $2.25	553.50
955 days, at $2.00	1,910.00
Total, at $2.55 per lin. ft.	$3,889.80

SECTION XIII.

COST OF RAILWAY AND TOPOGRAPHIC SURVEYS.

Rations for Men Camping.—In McHenry's "Rules for Railway Location" the following list of rations and supplies is given: The food is sufficient to support 14 men at least 30 days. The list is one used for surveying parties on the Northern Pacific Railway.

400 lbs. flour.
50 lbs. buckwheat.
40 lbs. oatmeal.
30 lbs. cornmeal.
25 lbs. rice.
10 lbs. tapioca.
10 lbs. sago.
10 lbs. barley.
10 lbs. cornstarch.
10 lbs. baking powder.
3 lbs. soda.
12 packages yeast cakes.
150 lbs. sugar.
20 lbs. salt.
50 lbs. coffee.
10 lbs. tea.
5 gals. syrup.
1 gal. vinegar.
400 lbs. potatoes.
50 lbs. beans.
20 lbs. onions.
2 cases (24 qts.) tomato
2 cases corn.
1 case peas.
1 case pears.
1 case cherries.
2 cases peaches.
1 case milk.
1 case coal oil.
2 lbs. mustard.
1 lb. ground pepper.
½-lb. ginger.
½-lb. cinnamon.
¼-lb. allspice.
¼-lb. nutmegs.
1 bottle lemon extract.
1 bottle vanilla extract.
6 bottles pickles.
6 bottles catsup.
8 bottles Worcester sauce.
100 lbs. ham.
100 lbs. bacon.
25 lbs. dried beef.
25 lbs. codfish.
40 lbs. lard.
25 lbs. cheese.
60 lbs. butter.
1 case cornbeef.
50 lbs. dried apples.
50 lbs. dried peaches.
50 lbs. dried prunes.
10 lbs. dried currants.
1 box raisins.
1 box crackers.
1 box macaroni.
1 box soap.
12 boxes matches.
1 box candles.
2 lbs. lye.
10 lbs. sal-soda.

The total net weight of food in this list is about 2,100 lbs., or about 5 lbs. of food per man per day, on the basis of 420 man-days. This is certainly ample. In fact men can live on much less if concentrated food that swells on cooking is used. The following is a list used by the author on a 30-day camping expedition where every superfluous pound of weight was cut out.

	One man 30 days	One man 1 day
Flour	25 lbs.	0.83 lb.
Oatmeal	8 "	0.27 "
Rice	4 "	0.14 "
Beans (dried)	8 "	0.27 "
Sugar	12 "	0.40 "
Salt	1 "	0.03 "
Butter	2 "	0.07 "
Bacon	10 "	0.33 "
Baking powder	1 "	0.03 "
Coffee	2 "	0.07 "
Tea	¼ "	0.01 "
Dried prunes	2 "	0.07 "
Pepper	¼ "	0.01 "
Condensed milk	3 cans	0 10 "
Total	79 lbs.	2.63 lbs

This list furnishes 0.23 lb. nitrogenous food, 0.30 lb. fat, and 1.30 lbs. starch and sugar per man per day. Dr. Pavy (Encyclopedia Britannica) states that a laborer requires daily 0.25 lb. nitrogenous food, 0.10 lb. fat, and 1.18 lbs. starch and sugar (carbohydrates). If the trip is to be a long one, 1½ ounces of juice of lime per man per day should be taken to prevent scurvy, unless potatoes can be carried along.

F. W. D. Holbrook, in Jour. Assoc. Eng. Soc., 1883, p. 180, gives the following rations for 20 men for 12 days, where all food has to be packed on the backs of men (1,040 lbs. food for 240 man-days):

12 bottles prepared mustard.
25 lbs. butter.
170 lbs. ham.
75 lbs. canned cornbeef.
50 lbs. mess pork.
300 lbs. flour.
100 lbs. granulated sugar.
50 lbs. brown sugar for syrup.
10 lbs. tea.
15 lbs. coffee.
70 lbs. beans.
25 lbs. rice.

25 lbs. dried apples.
25 lbs. dried peaches.
50 lbs. prunes.
25 lbs. raisins.
10 lbs. currants.
12 lbs. baking powder.
10 lbs. salt.
½-lb. ground pepper.
½-lb. ground ginger.
1 lb. ground cinnamon.
12 lbs. soap.
15 lbs. candles.
6 boxes matches (300 in box).

The U. S. Geological Survey ration list is as follows for 1 man for 100 days:

100 lbs. fresh meat, including fish and poultry.
50 lbs. cured meat, canned meat, or cheese.
15 lbs. lard.
80 lbs. flour, bread or crackers.
15 lbs. cornmeal, cereals, macaroni, sago or cornstarch.
5 lbs. baking powder or yeast cakes.
40 lbs. sugar.
1 gal. molasses.
12 lbs. coffee.
2 lbs. tea or cocoa.
10 cans condensed milk, or 50 qts. fresh milk.
10 lbs. butter.
20 lbs. dried fruit, or 100 lbs. fresh fruit.
20 lbs. rice or beans.
100 lbs. potatoes or other fresh vegetables.
30 cans of vegetables or fruit.
4 ozs. spices.
4 ozs. flavoring extracts.
8 ozs. pepper or mustard.
3 qts. pickles.
1 qt. vinegar.
4 lbs. salt.

Eggs may be substituted for fresh meat in the ratio of 8 eggs for 1 lb. of meat. Fresh meat and cured meat may be interchanged on the basis of 5 lbs. of fresh for 2 lbs. of cured. Dried vegetables may be substituted for fresh vegetables in the ratio of 3 lbs. of fresh for 1 lb. of dried.

This ration list weighs 5.3 lbs. per day per man, and it costs about 50 cts. per day per man. The list was based originally on the U. S. army ration, but has received some modifications dictated by experience.

Equipment for and Cost of Railroad Surveys.—Mr. F. Lavis, in Trans. Am. Soc. C. E., Jan., 1905, has given valuable information on railway surveying from which the following data have been abstracted: The work was done for the Choctaw, Oklahoma and Gulf Railroad (now part of the Rock Island System), in Oklahoma, Indian Territory and Northern Texas, under F. A. Molitor, Chief Engineer. The following is a list of the camp outfit:

1 office tent with fly, 14 × 16 ft.
3 tents, 14 × 16 ft.
1 cook tent, 16 × 20 ft.
3 drafting and office tables.
6 camp chairs.
Map chest with necessary stationery, paper, etc.

Dining Table.

3 dozen agate ware dinner plates.
3 dozen agate ware cups.
2 dozen agate ware saucers.
2½ dozen steel knives.
2½ dozen steel forks.
2½ dozen German silver teaspoons.
1½ dozen German silver dessert spoons.
1 dozen German silver tablespoons.
½ dozen tin salt boxes.
½ dozen tin pepper boxes.
¼ dozen round agate ware pans, 2 qt.
½ dozen round agate ware pans, 1 qt.
1 dozen round agate ware pans, 1 pt.
1 carving knife and fork.
7 yds. oilcloth, 48 ins. wide.
3 standard trestles.
5 boards, 12 by 1½ in. by 18 ft. (dressed).

Cooking Utensils.

1 No. 8, 6-hole, wrought-iron range.
1 tea-kettle.
1 large cast-iron pot.
1 small cast-iron pot.
2 large frying pans.
1 small frying pan.
2 griddles.
4 tin pans with covers, 1 gal. each.
2 stewpans.
1 3-gal. coffeepot.

Cooking Utensils.

1 gal. teapot.
4 dripping pans.
6 baking tins for bread.
12 tin pie plates.
2 butcher knives.
1 steel.
2 large meat forks.
1 chopping knife.
1 meat saw.
2 large iron spoons.
1 soup ladle.
1 cake turner.
1 flour sieve.
1 colander.
1 5-gal. tin dishpan.
1 5-gal. tin bread pan with cover.
1 chopping bowl.
1 bread board.
1 rolling-pin.
1 biscuit cutter.
1 nutmeg grater.
1 coffee mill.
1 spring balance.
6 galvanized iron buckets.
6 tin dippers (one for each tent and two in cook tent).
2 can openers.
1 corkscrew.
1 broom.
1 scrubbing brush.
1 alarm clock.
1 table (same as drafting tables).

Miscellaneous.

½ dozen Dietz lanterns.
3 large tin lamps (central-draft, round wicks).
2 large galvanized-iron washtubs.
1 washboard.
4 Sibley stoves (4 lengths of pipe with dampers, 12 lengths of plain pipe).
2 water kegs, 2 gal. each.
6 washbasins.

Tools.

1 grindstone and fittings.
1 monkey wrench.
1 pick.
2 shovels.
1 short crowbar.
1 hand-saw.
1 cross-cut saw.
2 hand-axes.
4 chopping-axes.
½ dozen axe handles.
1 bundle sail twine.
½ dozen sail needles.
1 sail palm.
10 assorted sizes wire nails.
100 ft. manila rope, ¾-in.

Lunch Box.

2 dozen agate ware dinner plates.
2 dozen agate ware saucers.
1½ dozen steel knives.
1½ dozen steel forks.
1½ dozen German silver teaspoons.
1½ dozen German silver dessert spoons.
1 2-gal. coffeepot.

Each locating party was organized as follows:

Locating engineer	$150 to $175
Assistant locating engineer	115 to 125
Transitman	90 to 100
Leveler	80 to 90
Draftsman	80 to 90
Topographers, two*	80 to 90
Rodman	50
Head chainman	50
Rear chainman	40
Tapemen, two*	30
Back flagman	30
Stake marker	30
Axemen (three to five as necessary)	25 to 30
Cook	50
Cook's helper	20
Double teams and driver, furnish their own feed, driver boarded in camp	65 to 90

Each man was supplied by the company with subsistence when in camp, but was required to provide himself with an army cot and sufficient bedding, and advised to provide a substantial canvas covering for the latter, an ordinary wagon cover, costing from $3 to $5, being the most easily obtainable and most satisfactory.

Most of the lines ran through a rather badly broken up, rolling country, with short cross-drainage, about 75% being wooded. Topography was taken 300 ft. on each side of the line, a hand level and rod being used, distances out were paced, and 5 ft. contours located and sketched. The average amount of grading was 100,000 cu. yds. per mile;

*One of the topographers assisted by two tapemen, with a transit determined land lines and drainage areas.

maximum grade, 0.5%; maximum curve, 2°. The cost of the surveys was as follows for 563 miles of preliminary and 188 miles of located lines:

PRELIMINARY LINES

	Party No. 1 July 5th to October 1st	Party No. 2 July 22d to October 20th	Party No. 3 August 1st to November 19th	Party No. 4 September 21st to October 21st
	87 days	90 days	111 days	30 days
Miles run and topography taken..	145.8	166.3	164.1	23.2
Miles run, no topography taken ..	39.3	....	16.0	3.6
Total miles preliminary run......	185.1	166.3	180.1	31.8
Total number payroll days.........	1380	1323	2033	635
Average daily number of men	15.9	14.7	18.3	21.2
Average miles per day per party..	2.12	1.85	1.62	1.06
Average daily cost, subsistence per man.........................	$0.37	$0.49	$0.38	$0.58
Average daily pay per man	1.81	2.03	1.66	1.66
Daily cost for teams..............	6.00	6.22	6.92	12.87
Contingencies	88.48	112.95	91.84	125.73
Daily cost of party	41.72	44.48	45.57	64.61
Cost per mile......................	19.61	24.07	28.08	60.95

LOCATED LINES

	Party No. 1	Party No. 2	Party No. 3	Parties Nos. 2 and 3 Combined	Party No. 4
	35 days	37 days	8 days	43 days	36 days
Miles located	56.0	37.8	7.6	42.6	39.2
Total number payroll days	1400	709	151	1498	1283
Average daily number of men ...	21.5	19.0	19.0	31.2	19.4
Average miles per day per party.	0.86	1.02	0.95	0.89	0.59
Average daily cost subsistence ..	$0.37	$0.39	$0.39	$0.40	$0.45
Average daily pay per man	1.72	1.61	1.61	1.71	1.60
Daily cost for teams..............	6.69	5.75	5.39	10.33	6.76
Contingencies	143.36	46.76	15.70	196.00	133.84
Daily cost of party	53.90	45.22	45.12	80.29	48.54
Cost per mile	62.57	44.33	47.50	90.47	81.72

The preliminary lines run by Party No. 1 were over a severe country, involving the heaviest construction work on the whole line. Party No. 3 also had much difficulty in getting a grade between certain points. Party No. 2 had the lightest country. Party No. 4 worked only a short time and the cost of moving a long distance from other work is included. It is probable that the cost of work done by this party was really about 60% more than the others per mile, instead of 100% more.

On the locating work, Party No. 1 had an expensive sounding party consisting of a man in charge, 4 or 5 laborers and a team. Parties Nos. 2 and 3 were combined, after each had run a short distance of located line separately, which increased the unit cost of the located line, as shown.

The total cost of 188 miles of located line was $192 per mile of located line, and this includes the cost of running the preliminary lines.

Cost of Railway Surveys.—In making a railway survey along the Columbia River, in open rolling country, my records show that a topographical party, consisting of 1 topographer and 2 rodmen, averaged 1½ miles a day, taking a strip 400 ft. wide, contours 5 ft. apart. A hand-level and tape were used. In this same country a leveler and rodman could readily run 6 miles of profile levels in a day, although it was safer to count on 4 miles.

On another similar survey in Southern New York State, in comparatively level country, a transitman, two chainmen and a stake artist, averaged 2 miles of transit line per 8 hrs. Station stakes were set every 100 ft. This same party, later, took a belt of topography 500 ft. wide, at the rate of 1¼ miles a day, setting a transit up at each station and taking telemeter readings for distance and level readings for elevation with long bubble of transit.

The cost of a preliminary railroad survey, near Lake Erie, was as follows, using stadia measurements:

Chief of party	$5.00
Transitman	3.00
Recorder	3.00
5 rodmen, at $2	10.00
Total salaries per day	$21.00

This party ran 46 miles in 30 days, several of which were stormy, and they took a belt of topography 800 ft. wide. The cost was about $14 a mile, or $90 a square mile for the field work.

Using the chain method it took a party 24 days to run 45 miles.

In Trans. Am. Soc. C. E., Vol. 31, p. 81, Mr. M. L. Lynch states that one mile of line a day is a fair average in partly timbered country, for preliminary work. He gives the average cost of surveys at $60 a mile of located line.

Mr. Kenneth Allen states that in Kansas prairies he ran 312 miles of stadia line in 5.7 months, or 2.1 miles per day, a party costing as follows per day:

Transitman	$6.00
Leveler	4.00
2 rodmen, at $2.50	5.00
Axman	2.00
Teamster and team	3.00
Total per day	$20.00

The cost was $11 a mile. Bench levels were run ahead of the transit. The best day's run was 8 miles.

The Cost of Transit Lines in Heavy Timber.—In running transit lines through the dense timber of Western Washington, for roads and railways, I have found that a party of 6 men (consisting of a transitman, two chainmen, two axmen and a flagman, who also served as an axman) averaged about 1,800 ft. of line run per ten hours. It was exceptional that 2,000 ft. were averaged even for two or three days. No trees more than a foot in diameter were chopped; but the growth of great firs and cedars (occasionally one was 10 ft. in diameter), and the mass of fallen timber under foot made the advance slow. Where the timber was not so dense, it was possible to run from 3,000 to 5,000 ft. a day, setting station stakes every 100 ft. In running a traverse along a country road, where there was no tree-chopping at all, the same party would run 6 miles a day.

In running profile levels over these transit lines, a leveler and rodman would average 4,000 ft. a day in rough

and densely wooded country; and 6,000 ft. in wooded country where the fallen timber did not retard walking so much. In all cases the actual time either on transit or level work averaged 8 hrs. per day, and about 2 hrs. per day were consumed in going to and from camp.

The foregoing records apply to lines aggregating several hundred miles in length, and are given partly from memory as my original detailed notes were lost in a fire.

Cost of Topographic Survey for 160-Acre Park.—In the State of Washington the author was in charge of a survey for a small city park of 160 acres. The work was done in August, 1892, with a party of 5 men, whose daily wages were as follows:

Transitman	$5.00
Recorder	3.00
2 chainmen, at $2.50	5.00
1 axman	2.00
Total per day	$15.00

This party was engaged 26 days in field work. In addition, a draftsman and computer was engaged for 40 days reducing the notes and plotting the map to a scale of 100 ft. to the inch, contours 10 ft. apart. The cost of the survey and map was, therefore, as follows:

Field work, 26 days, at $15	$390
Office work, 40 days, at $3	120
Total, 160 acres, at $3.20	$510

This is at the rate of $2,040 per sq. mile. This high cost was due to the roughness of the ground and to the fact that about half the area was densely timbered. The area surveyed was a hill about 350 ft. high, cut up by a number of gulches. A traverse line, 2 miles long, was first run to enclose the hill, station stakes being set every 100 ft., using a tape and transit. Then 10 parallel cross-lines were run along ridges through the woods over the hill, using tape and transit. The aggregate length of these cross-lines was 3 miles. Profile levels were taken with a Y-level along all the transit lines. Contours were located by means

of the stadia, the transit being set upon hubs on the transit lines. The density of the timber greatly retarded the stadia work, due to the axe work necessary. Were I to repeat this work, I should run a traverse around the area as before, chaining and leveling; then all the necessary cross-lines over the hill would be run, using the stadia. Where woods are heavy it is necessary to run such cross-lines close together. I should increase the number of axmen, and have rodmen also serve as axmen.

Cost of Topographic Survey of St. Louis.—In Engineering News, Oct. 31, 1891, Mr. Oliver W. Connet gives the following: The area covered by triangulation was 30 sq. miles, the average length of the sides of the triangles being 1½ miles. About 92½ miles of precise levels were run in duplicate at a cost of $30 per mile, four benches per mile. The stadia method was used for topography, contours being 3 ft. apart, about 300 points being located by a party in a day. The party consisted of 1 topographer, 1 recorder, 3 stadia men, and 1 utility man. The average was 3.65 points per acre. The time of a party occupied in field work for 23⅓ sq. miles was: Triangulation, 62 days; precise levels, 114 days; topography, 248 days; total, 424 days. The cost was:

Triangulation	$1,812 or	11%
Precise levels	2,762 or	16%
Topography	6,060 or	36%
Office work (reduction of notes and plotting)	6,266 or	37%
Total	$16,900 or	100%

This is equivalent to $725 per sq. mile, or $1.13 per acre. The average cost of the party per day, including transportation, instruments, etc., was:

Triangulation	$29.25
Precise levels	24.25
Topography	24.50

Cost of a Stadia Survey, Baltimore.—Mr. R. A. MacGregor, in Trans. Am. Soc. C. E., Vol. 44, p. 112, gives the

following on the cost of a stadia survey of the City of Baltimore, Md. The map was plotted on a scale of 200 ft. to the inch, and fences, roads, houses (with some details of houses), 5-ft. contours, wooded and cultivated areas, creeks, etc., were shown. Everything was plotted in the field. The average error of closure was 1 in 700. The average number of shots was 6,400 per sq. mile. The number of shots per day averaged 180, the maximum was 349, all the plotting and sketching being done in the field. The shots were taken and recorded by the recorder, and plotted by the draftsman, who stood nearby; the topographer in charge did the sketching. The cost of this field work alone was $850 per sq. mile for an area of 33.3 sq. miles.

Cost of Topographic Survey, Westchester Co., N. Y.—Mr. G. L. Christian, in Trans. Am. Soc. C. E., Vol. 44, p. 115, gives the cost of making a survey in July, 1896, of a 57-acre tract of land in Westchester County, N. Y. Three-fourths of the tract was wooded, with much thick underbrush. The land was much broken, having a total rise of 150 ft., with slopes of 2% to 40%. The transit lines (12,750 ft.) covered the controlling points, stakes being set every 50 ft., and profile levels taken with Y-level. From these lines, with a hand level and tape, the 5-ft. contours were located. The map was plotted on a scale of 100 ft. to the inch. The cost per acre was as follows:

Running transit lines	$0.40
Running Y-levels	0.19
Contours with hand level	0.53
Stakes	0.07
Plotting transit lines	0.13
Plotting contour lines	0.15
Total per acre	$1.47

This is at the rate of $940 per sq. mile.

Cost of Topographic Survey Near Baltimore.—Mr. Kenneth Allen, in Trans. Am. Soc. C. E., Vol. 44, p. 113, gives the following relative to the cost of stadia surveys made for the Baltimore Sewerage Commission:

Survey	I	II	III	IV	V
Contour interval....	5 ft.	5 ft.	5 ft.	2.5 ft.	2.5 ft.
Scale of map	1″=800′	1″=800′	1″=400′	1″=200′	1″=200′
Area, square miles..	2.04	2.75	4.83	0.823	0.733
Area, timbered......	....	....	47%	....	27%
Area, water surface.	....	....	3%	12%	18%
Area, per day, water surface............	0.157	0.131	0.079	0.052	0.052
Salaries per sq. mile	$54.90	$78.00	$140.20	$323.61	$256.21
Expenses " "	11.91	16.49	28.54	30.73	13.50
Cost per sq. mile....	$66.81	$94.49	$168.74	$354.34	$269.71

These costs do not include mapping done in the office, but do include maps made in the field. In surveys I. and V. the ground had gentle slopes; in III. the range of elevation was 125 ft., but in the other areas it did not exceed 40 ft. Comparing I. and IV. shows the increased cost where 2.5-ft. contours are located. Comparing I. and II. shows the economy of reading bearings with a compass (instead of with a vernier) and setting up on alternate points which was done in survey I.

Mr. Kenneth Allen, in Trans. Am. Soc. C. E., Vol. 30, p. 614, gives the following data: A stadia survey made for the Philadelphia Water Dept., in 1884, covered 446 square miles and occupied 162 days field work in the Perkiomen Water Basin, in Bucks, Montgomery and Lehigh Counties. The contours were 10 ft. apart plotted on a scale of 400 ft. to the inch. All roads, buildings and timber outlines were shown. The party consisted of 1 transitman and 1 rodman; the average area covered per day taking notes in the field was 0.434 square mile; the average area covered per day plotting in the field was 0.31 square mile.

On a survey in the Connellsville coke region, a survey similar to the above, but more detailed and plotted to a scale of 600 ft. to the inch, contours 10 ft. apart, covering an area of 168 square miles, cost $116 per square mile, including the location of farm boundaries, coal outcrops and areas, and the reduction of all previous surveys to the same scale. The cost of the field work on the topography alone was, however, only $40 per square mile, or about one-third the total cost. The cost of engraving and publishing was about $30 per square mile more.

Cost of Three Stadia Topographic Surveys.—Mr. F. B. Maltby, in Jour. Assoc. Eng. Soc., 1896, has an article

on "Methods and Results of Stadia Surveying," from which the following abstracts have been made:

A party should consist of an observer, a recorder, and 2 to 4 rodmen. A good observer in open country can locate 500 points a day for a map of 500 ft. to the inch. This means about 5½ or 6 hrs. of actual observing, and gives an average of 1½ shots per minute. Two men using the Colby protractor (one calling off and one plotting) plotted 216 shots per hour, as the average of 25½ hrs.

A stadia line, 15 miles long, over which levels were run, checking on each stake, showed discrepancies between consecutive stakes as high as 0.2 ft., but the total error for the 15 miles was less than 1 ft.

The cost of stadia surveys varies widely. The topographical survey of Baltimore, for topography alone, excluding triangulation and precise levels, cost $1.50 per acre. The scale of the map is 200 ft. per in., and all buildings, streets, alleys, etc., are located. The cost of the topography of the survey of St. Louis was 73 cts. per acre, scale of map the same, but few buildings and few street corners were located. A topographical survey of 3,000 acres, near Madison, Ill., in 1893, cost 50 cts. per acre including mapping; scale was 400 ft. per in., and all buildings, fences, railroads, etc., were located.

Several different tracts of land near St. Louis, of 100 to 200 acres, were surveyed for 20 to 40 cts. per acre. In these cases a scale of 400 ft. per in. and a 2-ft. contour interval, and only the configuration of the ground were required.

A survey of 9,300 acres in Southwest Texas, in 1894, was made; 2-ft. contours; and 400 ft. per in. scale; ground was rolling and partly covered with brush; condition favorable; cost, 7 cts. per acre.

Topographical work on the Mississippi River, in 1891, cost $36 per sq. mile; on the Missouri River, in 1895, $31 per sq. mile, or 5 to 5½ cts. per acre. Scale was 1,000 ft. per in., contours 5 ft. apart, all buildings, roads, fences, limits of culture, etc., located. This cost includes a system of tertiary triangulation, but does not include mapping.

Cost of Surveys, Erie Canal.—In Engineering News, June 28, 1900, Mr. D. J. Howell describes in detail the

methods of making surveys for the Mohawk Ship Canal, 90 miles along the Mohawk Valley from the Hudson River westward to Herkimer. The work was done by stadia parties, consisting of 1 chief, 1 observer, 1 recorder and 4 rodmen. The area mapped was 47,400 acres, of which 6,600 are river. The average cost was 86 cts. per acre, including soundings of the river, field and office work, but excluding test pits and borings. Contours were 2 ft. apart; map scale 1 in 2,500. A cross-country survey, 25 miles long, embracing 7,600 acres (no villages or cities), cost 27 cts. per acre for the field notes and the reduction of the notes ready for plotting. The cost of the plotting was estimated to be about 23 cts. per acre more, making the total cost about 50 cts. per acre. The men were well trained and the weather was favorable on this 25-mile stretch.

Mr. William B. Landreth, in Trans. Am. Soc. C. E., Vol. 44, p. 92, discusses the methods and cost of stadia topographic surveys made to determine the location of reservoirs and conduit lines for the Rome level of the Deep Waterway on the Oswego-Mohawk-Hudson Route. The surveys were made between Aug. 1, 1898, and June 1, 1899, scarcely any time being lost from bad weather. A party consisted of 1 engineer in charge, 1 transitman, 1 recorder, 3 or more stadia rodmen, 2 or more axmen, 1 draughtsman, and 1 computer. Each rodman was given a particular class of work, one following streams, another taking roads, another woods, and so on. When convenient all rodmen kept on the same side of the transit. Contour intervals were 10 ft. on the Salmon River and the Black River surveys, and 5 ft. on the Fish Creek line. At the close of each day the field party reduced the stadia notes. The scale of the Salmon River and the Black River maps was 1:10,000, and of the Fish Creek map, 1:5,000. About 65% of the Salmon River area is covered with small second growth timber and swamps. The country is rough. The Black River Valley, between the villages of Carthage and Lyons Falls was surveyed up to the 790-ft. contour. Only 25% of the area is wooded, and the country is not very rough. The Fish Creek Valley, from 2 miles above Williamstown, to 2 miles below Taberg, a distance of 21 miles, was surveyed, the survey covering the valley and a portion of the side

slopes to an elevation of 75 ft. above the creek. The ground was mostly grazing and farm land, 40% of which was timbered. The cost of the three surveys, including finished maps, traveling expenses, etc., was as follows:

	Salmon River	Black River	Fish Creek
Area, square miles	15	85	19
Set-ups	771	600	451
Shots	3,838	11,166	11,776
Square miles per day	0.32	1.81	0.45
Field work per square mile	$66.00	$16.50	$54.00
Map work per square mile	14.00	7.00	25.00
Total per square mile	$80.00	$23.50	$79.00

Note.—The cost of the base line surveys for the Salmon River and Fish Creek work, and for one-third of the Black River, is not included in the costs above given; the costs include no leveling, but only the stadia field work and mapping, excepting on the Black River where base line and leveling costs for two-thirds the territory are included.

Cost of U. S. Deep Waterway Survey, N. Y.—Mr. A. J. Himes, in Trans. Am. Soc. C. E., Vol. 44, p. 105, gives the following data on the U. S. Deep Waterways Surveys for a 30-ft. canal along the Oswego and Mohawk Rivers, a distance of 91 miles. A sufficient number of stadia readings was taken to develop 2-ft. contours. About 83% of the area was mapped on a scale of 1:5,000; the other 17%, on a scale of 1:2,500. There were 12 sq. miles of soundings made in Oswego Harbor and Oneida Lake, and plotted; and an area of about 78 sq. miles of Oneida Lake and Oswego Harbor was determined by triangulation. There were, besides, 121 sq. miles of land topography taken. All buildings, roads, railroads, property lines, streams, orchards, swamps, etc., were located. A stadia party consisted of 1 instrumentman, 1 recorder and 3 rodmen, with sometimes 1 laborer for cutting brush or rowing a boat. Each night the party reduced the stadia notes and calculated the coordinates. The error of closures was readily kept within 1 in 700; and errors in elevation seldom exceeded 1 ft., being usually less than 0.5-ft. Sights 2,000 ft. long were often taken. Charts were found to be much better than tables for stadia reductions. The work was begun Oct. 23, 1897, and finished Nov. 5, 1898. In no month were

more than 5 days lost on account of bad weather. The average number of readings was 1,440 per sq. mile. The minimum average area covered per day by one party on a single piece of work was 0.058 sq. mile. The maximum was 0.257 sq. mile. The average for the whole survey was 0.123 sq. mile per party per day. The cost was as follows per sq. mile:

Field work	$179
Mapping	101
Total per sq. mile	$280

This is exclusive of swamps, and lakes not sounded.

Cost of Government Topographic Surveys.—Mr. Marcus Baker, in Trans. Am. Soc. C. E., Vol. 30, p. 619, gives the cost of Government topographic surveys in many European countries, to which the reader is referred. The U. S. Geological Survey of New Jersey was begun in 1877 and finished in 1887, covering an area of 7,894 square miles, with contours 10 and 20 ft. apart. The cost was $6.93 per square mile, which includes all expenses in producing a map ready for the engraver. The engraved map is on a scale of about 1 mile per inch. A similar survey of Massachusetts, made 1884-1888, contour interval 20 ft., cost $13 per square mile. A similar survey of Rhode Island, made 1888-1889, cost $9 per square mile. A similar survey of Connecticut, 5,004 square miles, made 1889-1890, on a scale of 1 mile per inch, 20-ft. contours, cost $9.80 per square mile for map ready for engraver.

A topographic map of the banks of the Mississippi River, from Cairo to the Gulf of Mexico, was completed by the Government in 1884, at a cost of $51 per square mile for 1,954 square miles of land and water surface. The manuscript map was on a scale of 1:10,000, embracing the river and a strip of land ¾ mile wide on each side. The river was carefully sounded.

Mr. Baker gives estimates of the cost of surveys made by the Coast Survey, but these estimates are strongly disputed, moreover they are of minor value to engineers in general practice, so the reader is referred to the Transactions for the data.

The N. Y. State Engineer's Report, 1897, gives the cost

of topographical surveys, for the Dept. of the U. S. Geol. Survey, as follows per square mile, contours 20 ft. apart, and map on a scale of about 1 mile to the inch:

	Sq. mile.
Triangulating (1,370 sq. miles)	$2.00
Topography	8.70
Office work	0.60
	$11.30

The total cost of 15,118 sq. miles, for field and office work, had been $11.06 per sq. mile. A table giving the cost of 2,200 sq. miles shows a range of $4.35 to $25 per sq. mile, the average being $10.05 for field and office work, of which $8.43 was the cost of field work. The cost of office work ranged from $1.15 to $4.05 per sq. mile, and averaged $1.62.

Cost of Sounding Through Ice.—In Engineering News, Oct. 11, 1894, Mr. Joseph Ripley describes the construction and use of an ice boring machine, operated by bevel gear, for boring 3-in. holes through ice. Before the use of this machine, holes were chopped by axes at a cost of about 8 cts. per hole through 2 ft. of ice. With the machine, operated by two men, the average time was less than ½ min. per hole, through 26 ins. of ice, overlaid by 2 ft. of snow, including all delays. The time of actual boring was about 8 seconds per hole. The sounding party consisted of 1 chief, recording soundings, 2 men sounding, 6 men operating three boring machines, 2 men moving tag lines and marking places for holes, 3 men shoveling away snow after holes were bored, 1 gage observer and 1 cook. Such a party averaged 3,000 holes per day of 8 hrs. at a cost of $1,000 per month, the working day being 8 hours. With 25 working days in a month, the cost is 1⅓ cts. per hole.

In U. S. Eng. Report, 1903, Vol. 10, Part 2, p. 1896, the following is given:

An ice boring machine will bore a 2½-in. hole through 2 ft. of solid ice in 5 secs. A party can take 300 soundings per hr. through ice 2 ft. thick, in water 23 ft. deep, holes spaced 10 ft. × 50 ft. The best record for 8 hrs. was 2,749 soundings, ice being 13 ins. thick. The cost of soundings was 3 cts. each for field work, including locating the holes.

SECTION XIV.

COST OF MISCELLANEOUS STRUCTURES.

The Cost of Fences.—A barbed wire fence was built under the following specifications:

"Posts to be of oak or tamarack, 5 ins. diameter and 8½ ft. long, spaced 16½ ft. apart, c. to c., and set 3½ ft. deep in the ground. The height of fence to be 4 ft. 9 ins., formed of four lines of 4-barb wire, spaced 12, 14, 15 and 16 ins. apart measured from the ground up."

	Per mile.
350 posts, including braces, at 10 cts	$35.00
1,500 lbs. 4-point barbed wire, at 5 cts	75.00
40 lbs. staples, at 5 cts.	2.00
Labor	43.00
Total	$155.00

This 10 cts. per post was a very low price, due to the fact that posts were cut from trees near the work. Posts are frequently 5 to 10 cts. per lin. ft. of post, where they are imported by rail.

Where rail fences are built, the posts are usually spaced 8 ft. apart c. to c., and set at least 3 ft. deep. The fencing specified by the Mass. Highway Commission consists of cedar or chestnut posts, not less than 6 ins. diam. and 6½ ft. long, set 3 ft. in the ground, and spaced 8 ft. c. to c., bark peeled off. A top rail, 4 × 4 ins., and a side rail, 2 × 6 ins., are specified to be of dressed spruce; and both rails are notched into the posts and spiked. The fence is painted with one coat of white lead and oil. The usual contract price for such a fence in Massachusetts is 15 cts. per lin. ft., or $890 per mile. There are 660 posts, and 12,300 ft. B. M. of spruce per mile.

The wire fences of the Louisville & Nashville Ry. have posts 7 ft. long, with seven wires spaced 4, 4, 6, 8, 10, 12 and 12 ins. from the ground up. For one mile of fencing the following materials and labor are required:

	Per mile.
3 barbed hog wires (7.7 lbs. per 100 ft.)	1,218 lbs.
2 barbed cattle wires (7.14 lbs. per 100 ft.)	754 lbs.
2 plain ribbon wires (6.66 lbs. per 100 ft.)	704 lbs.
Total wire per mile	2,676 lbs.
Staples	49 lbs.
Posts, 10 ft. apart	528
Bracing, 1 × 6-in. yellow pine, ft. B. M.	440
Labor	$105

In soft soil a good workman, using an 8-in. post hole digger, will dig 100 post holes, 2 ft. deep, per day of 10 hrs.

Cost of a Gas Pipe Hand Railing.—A gas pipe hand railing for a small stone-arch bridge was made of three lines of 1½-in. pipe rails and posts. The weight of the pipe was 800 lbs. for 100 lin. ft. of railing (50 ft. on each side of the bridge). The cost was as follows:

100 lin. ft. of railing ready to erect	$65.00
Hauling 1½ miles	0.60
1 qt. asphaltum paint	0.20
Paint brush	0.20
9 lbs. sulphur, at 8 cts.	0.72
Iron kettle to melt sulphur in	0.40
Labor erecting railing, 17 hrs., at 35 cts.	5.95
Labor erecting railing, 2 hrs., at 15 cts.	0.30
Total for 100 ft. of railing	$73.37

The principal cost of erecting was the drilling of 48 bolt holes (½ × 2 ins.) in the stone coping. The bolts that passed through the cast-iron post bases were held with sulphur. The posts were made of 1½-in. gas pipe, crosses and tees. The 1½-in. pipe measured about 2 ins. outside diameter, which is a good size for hand railing.

On another job 100 lin. ft. of hand railing were built along an embankment. The railing was made of 3 lines

of ¾-in. gas pipe (1-in. diam. outside) made as above described, except that each post was fastened to an oak plank buried in the ground, and an inclined brace ran from each post to the plank. The cost of 100 lin. ft. of railing was:

100 lin. ft. railing and posts	$37.50
Labor erecting	31.50
Total	$69.00

Cost of a Brush and Stone Revetment.—Mr. W. R. DeWitt gives the following on building a brush and stone revetment along 8,200 ft. of river bank, on the Missouri River, near Cambridge, Mo. The work was done by company laborers for the Chicago & Alton Ry., in 1901, and is similar to nearby Government work which had proven satisfactory for 12 years previous. The bank was first graded down with a hydraulic giant having a 1¼-in. nozzle, water being supplied by a pump at 100 lbs. pressure. A grading force consisting of 1 steam-engineer, 1 fireman, 1 nozzleman, 1 watchman and 2 laborers graded 100 lin. ft. of bank, moving about 800 cu. yds. per day. The nozzle was started at the top of the bank and moved down the slope to the water's edge, cutting a true slope.

The grading was followed up closely by the gang weaving brush mattresses. Two barges 20 × 50 ft. were lashed end to end, and a platform and set of ways built thereon. The weaving was done on the ways. When the weavers reached the top of the ways, the boat was dropped down stream. The mattress is of willow brush, pieces being 1 to 2 ins. diam. at the butt, and 15 to 25 ft. long, woven with an over and under stitch, like the seat of a cane chair. It is 12 ins. thick and 86 ft. wide, and is strengthened and held by ⅜-in. galvanized wire cables anchored to 12 × 12-in. pine deadmen on the top of the bank. The mattress projects 3 ft. above low water. The mattress force consisted of 1 foreman, 10 laborers skilled in weaving, 10 laborers passing brush to the weavers, 3 laborers to pass the brush from scow alongside to the weavers' helpers, 5 laborers weaving the cables through the mattress, 3 laborers digging

and filling deadmen holes, and 1 waterboy, or 33 men in all, at $1.50 per day per man. This force would average 90 lin. ft. of mattress in 10 hrs., or 287 cu. yds. of mattress.

After a sufficient length of mattress was floating on the water, it was sunk by placing upon it stones weighing 100 to 200 lbs. each, which were delivered by a barge. A gang of 30 men would unload 150 cu. yds. of stone from the barge upon the mattress in 3 hrs., sinking 200 lin. ft. of mattress.

The bank above the mattress, which was graded to a 1:2 slope, was paved with rough one-man stone up to 2 ft. above high water, the thickness of the paving being 8 ins. at the top, increasing to 12 ins. at the low water line. A force of 28 men wheeled the stone on run planks from barges in the river, the extreme distance being about 60 ft. The width of the paving on the slope is 54 ft., and these 28 men, with 4 pavers, averaged 100 lin. ft., or 5,400 sq. ft., or 150 cu. yds., in 10 hrs. The stone layers began at the top (reversing the usual procedure), and laid the stone sloping uphill, so that each stone was self-supporting. Upon this rough slope wall (the stone of which received no hammer dressing), a layer of spalls and crushed stone 2 ins. thick was spread, and all joints were thus filled. The cost per 100 lin. ft. of this brush and stone revetment was as follows:

Grading bank, labor	$10.25
Grading bank, fuel and supplies	2.25
60 cords willow brush, delivered, at $1.75	105.00
800 lbs. ⅜-in. galv. cable, at 4 cts	32.00
48 clips (7/16-in. iron), at 5 cts	2.40
6 deadmen, 12 × 12 ins. × 4 ft., at $1	6.00
Labor weaving mattress	55.22
75 cu. yds. stone for ballasting, at $1	75.00
Labor ballasting mattress	6.50
150 cu. yds. stone for slope paving, at $1	150.00
Labor laying 150 cu. yds. paving	51.70
47 cu. yds. spawls, at $0.50	23.50
Labor spreading 47 cu. yds. spawls	15.43
Administration	18.25

Care of plant, $7.50; and repairs, $1.50	$9.00
Rent of plant	100.00
Surveys	5.00
Ice	3.00
Towage, other than for stone and brush	8.25
Total	$678.75

The plant consisted of 1 grading outfit, 1 mattress boat and 6 barges, 25 × 100 ft.

Cost of Clearing Land.—The cost of clearing the margins of Indian Lake, N. Y., for 35 miles, was about $12 per acre for 1,160 acres. Men were paid $1 a day and board; and the board cost about 50 cts. a day. Foremen (1 foreman to 20 men) were paid $35 a month and board. Each acre, it was estimated, ran from 50 to 75 cords of wood. Each laborer averaged one-fifth acre cut per day, including some piling, but no burning of the timber; so that the cutting cost $7.50 per acre. There was no large merchantable timber, all having been cut down years before. The growth was mostly small pines, balsams and various hardwoods. The methods of clearing are described in Engineering News, May 18, 1899, p. 314.

In the work for the filter beds at Brockton, Mass., 1894, there were 18.8 acres cleared and grubbed, of which 14.4 acres were standing pine. The trees varied from 6 to 24 ins. in diameter; and there were about 3 trees per sq. rod. When cut up, about 35 cords of wood per acre were obtained. The total cost of pulling and disposing of stumps was $112 per acre, or 23 cts. per tree. Wages of laborers were $1.50 a day.

The contract prices for clearing and grubbing through the dense forests on Puget Sound, Washington, often run as high as $500 an acre. This is probably the most difficult work of its kind in America.

A very common price for clearing and grubbing forest land in the eastern part of America is $50 an acre, when wages are $1.50 a day.

Cost of Cordwood and Cost of a Wire Rope Tramway.—In Engineering News, March 21, 1891, Mr. B. McIntire describes and illustrates a wire ropeway built by

him in 1884 in Mexico. He states that when the inclination of an endless traveling ropeway is greater than about 1 in 7 it will run by gravity, the speed being controlled by a brake. A ropeway running 200 ft. per min. with buckets at intervals of 48 ft., each carrying 160 lbs., will deliver 20 tons per hr. By using two clips close together on the rope, loads of 700 lbs. per bucket may be carried. This particular ropeway was used for carrying cordwood to a mine. Its total length was 10,115 ft. between terminals, and the difference in elevation was 3,575 ft. The longest span between towers was 1,935 ft., the shortest, 104 ft.; there were 10 towers and two terminals. Hewed timbers were used for the towers, being much better than round timbers in maintenance. The rope was 13/16-in. diam., plow steel, of 300,000 lbs. strength per sq. in., bought of the California Wire Works. It was transported on 7 mules in lengths of 2,250 ft., each mule carrying a coil 321 ft. long, with a piece 10 ft. long between mules. The coils were 24 ins. diam. There were 3 men required to every 7 mules. Care must be taken to lead the mules on a steep ascent to prevent a sudden rush that may throw a mule over a precipice. The ropeway, after erection, was lubricated best by using black West Virginia oil (instead of tar), applied continuously at the rate of a drop a minute. This was vastly better than intermittent oiling. The cost of this ropeway was as follows:

Upper terminal	$ 192.45
Lower terminal	218.00
5 trees fitted for towers	103.00
5 towers	854.25
Counterweight tower	169.00
Remodeling towers	332.00
Stretching, splicing and mounting rope, attaching clips and baskets	255.00
Total labor cost of construction	$2,123.70
Opening and maintaining roads	1,822.30
Ropeway, materials and transportation	15,454.00
Total cost in running order	$19,400.00

This is equivalent to about $10,000 a mile. During 9 mos. the ropeway was operated at a cost of $400 a month, and handled 660 cords per month; the items of cost being as follows for 9 mos.:

1 brakeman, at $52 per mo.	$ 468
3 men filling, at $26 per mo. each	702
1 man dumping, at $40 per mo.	360
1 man looking after line and oiling, at $26	234
Oil	117
Repairing (very heavy, $2.25 per day)	526
2 men wheeling wood away from terminal	468
2 men receiving wood from choppers and delivering it to packers	702
Total for 9 mos.	$3,577

It will be noted that the cost of labor was low, being $1 a day for common labor. The cost of cutting and delivering wood to the tramway was $2.20 per cord, and the cost of transporting by the tramway, as above given, was 60 cts. per cord (not including interest on the plant). During the previous year the cost of cutting and teaming wood had been $12 per cord. The total saving to the company, after deducting cost of tramway, was $33,500 the first year.

Cost of Lining a Reservoir With Asphalt.—In Trans. Am. Soc. C. E., 1892, Vol. 27, p. 629, Mr. James D. Schuyler discusses the use of California asphalt for lining two reservoirs of the Citizens Water Co., at Denver, Col.

The earth slopes of a reservoir were first sprinkled and rolled with a 5-ton slope roller, operated by a hoisting engine mounted on rails on top of the embankment. Slopes were 1⅓ to 1, and depth of water was 20 ft. Beginning at the bottom the asphalt was laid on the earth slopes in horizontal strips 10 ft. wide, 1¾ ins. thick, spread with hot rakes, tamped with hot tampers, and ironed with hot smoothing irons. Asphalt was hauled 2½ miles and delivered at a temperature of 250°. While the asphalt sheet was still warm, anchor spikes, of ⅛ × 1-in. strap iron 8 ins. long, were driven through the asphalt into the bank

in rows 1 ft. apart. Every other row was driven flush, the alternate rows being temporarily left projecting 1½ ins., to serve as a rest for 2 × 4-in. strips of lumber, forming steps for the workmen. When the finishing coat came to be applied these spikes were driven in flush.

The bottom was coated with asphalt 1 in. thick, and after tamping was rolled with a cold 5-ton steam-roller. The finishing coat of refined Trinidad asphalt, fluxed with residuum oil, was poured on hot from buckets and ironed with smoothers heated to cherry red. When first applied the irons produced a yellow smoke, and had to be moved rapidly, but thus only could a good bond be secured with the first coat.

The cost of asphalting a reservoir having a bottom area of 87,300 sq. ft. and a side-slope area of 65,300 sq. ft., or a total of 152,600 sq. ft., was as follows:

1,304 tons, 20% asphalt mastic, 80% sand, at $12.	$15,648.00
15 tons, 15% asphalt mastic, 85% sand, at $10..	580.00
86.21 tons liquid asphalt fluxed with oil, at $40.	3,448.40
Fuel for heating irons and for steam roller....	276.02
Lights	36.00
Tools	179.75
Pegirons, material and labor of cutting and dipping in asphalt	650.00
Labor	1,921.50
Use of roller 6 days	60.00
Total for 152,600 sq. ft., at 14.94 cts. per sq. ft..	$22,799.67

Mr. Schuyler informs me that, as nearly as he can remember, men were paid $1.75 per 10-hr. day, although possibly the rate was $2 a day.

The second reservoir was lined in a manner similar to the first, just described. The total area of bottom and slopes was 143,670 sq. ft., which required 1,156 short tons of the asphalt and sand mixture for the first coat; and as this mixture weighed 127 lbs. per cu. ft. after compression, the average thickness was 1.53 ins., requiring 16 lbs. per sq. ft. The finishing coat was ⅛ to ¼-in. thick, and re-

quired 1.24 lbs. of asphalt per sq. ft. The cost of lining this reservoir was as follows:

	Cts. per sq. ft.
Materials for first coat	8.98
Materials for second coat	2.48
Labor, fuel, spikes, etc........................	1.99
Total cost of both coats	13.45

In preparing the mastic for the first coat 78% of La Patera asphalt and 22% of Las Conchas flux were boiled together in open kettles for 12 hrs., at 250° to 300°, with frequent stirring. Then 20% (by weight) of this mastic was mixed with 80% of sand heated to 300°, a cylinder with strong paddles being used for the mixing, which took about 2 mins. The charge was dumped into a cart, hauled to the reservoir and dumped upon a wooden platform, and thence taken in hot scoops, spread and raked. Hot rollers were then used, and they were superior to tamping and ironing. These rollers were made from sections of cast iron pipe, turned smooth on the outside, and fitted inside with a hanging basket in which a fire was maintained. For the bottom rolling a 30-in. pipe was used; for the slopes a 14-in. pipe, pulled with a ⅜-in. wire cable passing over a pulley at the top of the slope, was used.

Asphalt as a reservoir lining possesses several advantages: It will not crack even when there is considerable settlement of the embankment. If cracks do occur it is easily patched, the new material uniting perfectly with the old.

To prevent earth from crumbling and rolling down upon the partly completed asphalt, it is often wise to plaster the earth with a mortar of sand, cement and lime to a thickness of nearly 1 in., which will cost about ½ ct. per sq. ft. On this should be spread a thin coat of liquid asphalt as a binder, which would have the additional advantage of protecting the asphalt from ground water. To prevent accumulated ground water from forcing off the asphalt lining, when the water in a reservoir is drawn down, it is often necessary to provide broken stone drains back of the lining. These drains may be led to a receiving

well connected with the reservoir by pipes provided with valves opening automatically into the reservoir.

Ice, 18 ins. thick, has been frozen fast to the asphalt lining all around, and the water lowered and raised again 3 or 4 ft. without damaging the lining in the least.

I am informed (Sept., 1904) by Mr. Geo. S. Prince, Asst. Ch. Engr. the Denver Union Water Co., that this asphalt lining has not been durable. "It has run considerably on the slopes and this has resulted in the cracking and disintegrating of the asphalt so that considerable expense has been involved in keeping it in anything like serviceable condition and we would not consider using it again in this connection, preferring rather to employ concrete linings."

Cost of Handling and Screening Cinders.—Cinders are often used in concrete and for other purposes. The following data have been abstracted from an article in Engineering News, Aug. 18, 1904, by Mr. Ernest McCullough:

The cost of unloading and screening soft-coal locomotive cinders for a filter bed was as follows: The filter bed consisted of a lower layer of cinders 27 ins. thick and an upper layer 9 ins. thick. The lower layer comprised all cinders that would pass a screen of 1-in. mesh, but that would not pass a ⅜-in. mesh. The upper 9-in. layer would pass a ⅜-in. mesh, but not a ⅛-in. mesh. Unscreened cinders were shipped in gondola cars holding about 32 cu. yds. each, and were unloaded near the filter bed, screened and conveyed in wheelbarrows to place. The freight on car load was about $36. In one shipment of 16 cars there were 2 cars of ashes so fine as to be rejected without screening. The others gave the following proportions:

Clinkers not passing 1-in. mesh	10%
Cinders passing 1-in., but not passing ⅜-in. mesh	75%
Cinders passing ⅜-in., but not passing ⅛-in. mesh	5%
Fine dust, under ⅛-in.	10%
Total	100%

It was found that cinders in a pile exposed for two weeks to the rain and weather were so disintegrated that 33% would pass a ⅛-in. mesh.

One man, using a coal scoop, would unload 32 cu. yds. from a car in 10 hrs., and as this yielded about 24 cu. yds. of coarse screened cinders, the cost of unloading was 6 cts. per cu. yd., wages being $1.50 a day. Another man, using a scoop, would shovel the cinders upon the first (1-in.) screen at the same rate. But it took two men, using ordinary square pointed shovels, to screen through the ⅜-in. screens, and these men screened the material twice, because it would not pass through these screens rapidly, nor at the first screening. A fair estimate of the cost of unloading and screening the coarse (1-in. to ⅜-in.) cinders is as follows. the cinders being measured in place in the filter bed:

	Per cu. yd.
Unloading cars	$0.06
Coarse (1-in.) screening	0.06
Fine (⅜-in.) screening twice	0.24
Wheeling and spreading in bed	0.08
Total	$0.44

The freight was about $1.50 per cu. yd. of screened cinders, and the cost of loading the cars about 16 cts. more, making a grand total of $2.10 per cu. yd. of coarse screened cinders in place in filter beds.

Since all the cost of loading, unloading and freight has been charged to the coarse cinders, the cost of the fine cinders (⅜ to ⅛-in.) was merely the cost of screening them twice through a ⅛-in. screen, or 24 cts. per cu. yd. plus 8 cts. for wheeling and spreading. When these fine cinders were perfectly dry, once over the ⅛-in. screen was enough; but, if very wet and largely dust, screening three times over the ⅛-in. screen was necessary.

Since the proportion of fine screenings (⅛ to ⅜-in.) was so small, it was necessary to buy a number of car loads of screenings and waste all the material over ⅜-in. size. The freight, when charged against the fine screenings, was about $12 per cu. yd. due to the fact that not more than 3 cu. yds. of fine screenings could be obtained from a car load. An attempt was made to grind up some of the coarse screenings using a farmer's feed mill operated by

horse power. The mill would grind at the rate of 7½ cu. yds. of cinders in 10 hrs., but so many iron nuts, bolts, washers, etc., were in the screenings that the mill was continually forced to stop, and finally its use had to be abandoned.

I may add that the specific gravity of soft coal cinders is 1.5 and that the voids are frequently as high as 60%, in which case 1 cu. ft. of cinders weighs 37½ lbs.

Cost of Puddle.—Puddle is a mixture of gravel and clay which is wet and rammed or rolled into place. Many engineers use the clay as they would a mortar to fill the voids in the gravel. A few engineers use the gravel merely to insure the crumbling of the sides and roof of any incipient hole in the puddle so as to fill it up.

Fanning gives the following proportions measured loose:

	Cu. yd.
Coarse gravel	1.00
Fine gravel	0.35
Sand	0.15
Clay	0.20
Total loose	1.70

This when mixed, he says, will make 1.3 cu. yds., and when thoroughly rammed 1.25 cu. yds.

Another mixture given is:

	Cu. yd.
Gravel	1.00
Sand	0.35
Clay	0.25
Total	1.60

This when mixed and spread makes 1.16 cu. yds., and when rammed 1.1 cu. yds.

When clay is not available, very fine sand and a little loam can be used to fill the voids in gravel. Where puddle is used to cover a large area, like the bottom of a reservoir, the gravel is first spread in a layer about 3 ins. thick, the clay is spread over the gravel, and the sand over the clay in their proper proportions. Then an ordinary

harrow is dragged by a team back and forth until mixing is complete. Water is next sprinkled over in amount sufficient to cause the mass to knead like stiff dough under a 2-ton sectional roller. Such a puddle is as heavy as concrete and resists abrasion almost as well. With labor at $1.50 and teams at $3.50 the cost is 8 cts. per cu. yd. for spreading by hand, 5 cts. for harrowing, 2 cts. for sprinkling and 5 cts. for rolling, making a total of 20 cts. per cu. yd. of puddle; but an exacting engineer can readily make the cost double this amount, bringing it to 40 cts. per cu. yd., which is about what it costs to spread, sprinkle and roll a cu. yd. of macadam.

Where puddle is used in confined places, like trenches, it must be mixed like concrete and rammed to place. The cost of mixing by hand and ramming the puddle is 30 to 50 cts. per cu. yd. On the Erie Canal, with wages $1.50 for 10 hrs., the contract prices for mixing and laying puddle ranged from 20 to 60 cts. per cu. yd., the average price being 35 cts., and this did not include the materials.

Cost of a Bridge Foundation Excavation and Coffer-dam.—Mr. Walter N. Frickstad gives the following data on bridge foundation work, done by force account, by the Southern Pacific R. R. in Nevada, year 1902-3. In crossing the Humboldt River the line made a very sharp angle with the river, but a skew bridge was not used. There were two abutments and one pier. To build the east abutment an L-shaped coffer-dam of sand bags, filled in between with earth, was used. The long leg of the L was 100 ft. long, and the short leg 40 ft. long. This enclosed a triangle of water, bounded by the two legs of the L-shaped coffer-dam and the shore line of the river. The sand filled sacks were wheeled to place and deposited by men provided with long handled shovels and sticks to guide them to place; but it was not found practicable to build the sacks up in tiers, for the air spaces in the sacks buoyed them so that they were easily displaced by the river current. It was intended to leave a 3-ft. space between two tiers of sacks, to be filled with puddle, but this space became choked with sacks. It was found impossible to pump out this dam with a one-man sewer "deluge" pump, so a bank of earth was deposited outside of the dam of

sacks. Where the current was swiftest, the earth was rushed to place with a steady stream of wheelbarrows, the coarsest gravel being used as a riprap on the loam and sand; and, in spite of current of 5 ft. per second, the embankment held its place. Then with 4 men on a shift, two working while two rested alternately in 15-minute periods, the dam was pumped dry in 2 days and 3 nights, at a cost of $19 per 24 hrs. To reduce the area, to be kept pumped out, a cross-wall of sacks, 30 ft. long, was put in. About 2,230 sacks were used, all told.

This work cost as follows:

Building L-shaped dam, 53 days, at $1.50........	$79.50
Filling its slope with earth, 32 days, at $1.50....	48.00
Building cross-wall of dam, 30 days, at $1.50....	45.00
Excavating mud and loose rock, 24 days, at $1.50	36.00
Pumping until masons were above water line, 85 days, at $1.50	127.50
Foreman, 9 days, at $3	27.00
Total	$363.00

While the masons were at work on the east abutment, the coffer-dam of the center pier was built in a manner that proved to be the cheapest and requiring the least equipment of all the methods of coffer-damming used. To get to bed rock there were 2 ft. of silt, 7 ft. of gravel and boulders and 5 ft. of boulders. Tests with long drills had led the engineers to believe that solid rock was 5 ft. nearer the surface, the boulders being mistaken for solid rock. The pier was of masonry with a sharp nose at each end, so the coffer-dam was made of similar shape and with a length of 55 ft. from nose to nose, and an outside width of 16 ft. The coffer-dam consisted of sheet piling driven by hand as fast as the excavation progressed inside, just as in ordinary sheeting of a sewer trench. The rangers, or waling pieces, to support the sheet piling were made of 8 × 17-in. Oregon pine, drift-bolted together to form a frame, as shown in Fig. 29. This frame was laid flat just above the surface of the water, being temporarily supported by a bar of river sand at one end and by a pair of wooden horses (4 ft. high) near the other end. These

horses were built and sunk in the stream, and planks laid out from the sand bar, upon which to push the frame to place on 1¼-in. gas pipe rollers by four men using pinch bars. About one-third of the frame overhung these horses, and the water was 7 ft. deep at the outer nose of the frame. Holes were dug 2 ft. deep under the three corners of the frame that rested on the sand bar, and temporary posts set in these holes to support that end of the frame. Then excavation was begun, 8-ft. lengths of sheet planking or piling being driven, starting at the nose of the frame. A heavy wooden maul was used to drive the sheeting. When 12 of these 3 × 12-in. sheeting planks had been driven down a short distance, earth and manure were piled out-

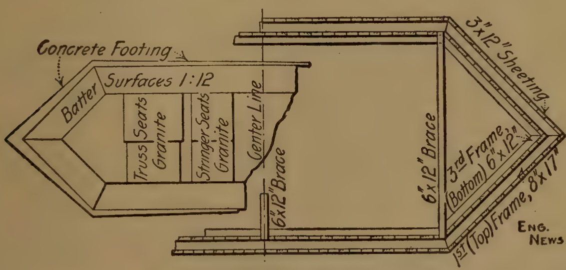


FIG. 29.

side. Then the lines of sheeting were continued out into the river, using longer plank. Finally several of the sheeting planks were temporarily spiked to the frame, the horses removed, and plank driven to close the gaps. Earth and manure were banked up outside the sheeting. It was found necessary to deflect the river current, which was washing away this earth and manure, and to do this a wing dam of sacks filled with sand was built, and coarse gravel and sand-filled sacks used to riprap the outer end of the earth and manure fill. The water was readily pumped out, and excavation begun. It was found that the sheeting was sloping inward, so a second frame was built of 6 × 12's inside the excavation and at the bottom of the sheeting; then the driving of the sheeting was continued and this second frame was lowered as the excavation progressed. Once the gravel caved and two sheet plank

were forced in, but quick work with brush, manure and earth closed the hole. When the excavation was 7 ft. below the water surface, and rock was not encountered, it was decided to build a third frame and drive a second tier of sheet plank inside, and sloping outward, as in Fig. 30. This was begun when the flow of water became so

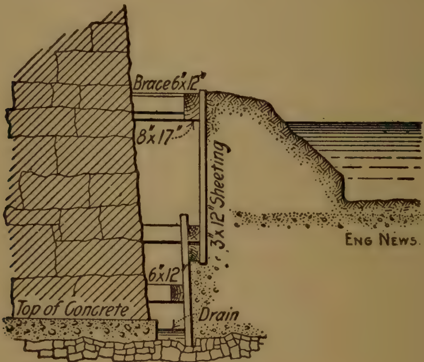


FIG. 30.

great that a 6-HP. Fairbanks, Morse & Co. combined gasoline engine and pump was installed, and no further difficulty occurred in getting down to bed rock. The cost of this pier excavation by force account was as follows:

Labor excavating, etc., 324 days, at $1.50	$ 486.00
Labor pumping, 136 days, at $1.50	204.00
Engine-runners, 50 days, at $3	150.00
Four-horse team, 6 days, at $6	36.00
Carpenter, 8 days, at $3	24.00
Foreman, 24 days, at $4	96.00
115 gallons gasoline, at 15 cts	17.25
300 sacks, at 15 cts.	45.00
10 M of pine, at $30	300.00
Total	$1,358.25
Salvage value of 5 M of pine removed	150.00
Total for 280 cu. yds. excav., at $4.30	$1,208.25

I have assumed the prices and rates of wages as above given, although in fact they may have varied slightly. The number of days' work and the amount of materials is exact. It will be noted that half the timber in the coffer-dam was recovered and used elsewhere. The cost of excavation was high, because no derricks were used, but the shoveling was done in stages; moreover, there was a large quantity of boulders, and trouble with pumps caused considerable delay.

The excavation for the west abutment, though much larger than for the pier just described, was done in the same manner. The coffer-dam inclosed an L-shaped area, about 60 ft. long on each leg of the L, and about 20 ft. wide. The waling frames were built in place after the site had been excavated to the water level with drag scrapers, and the second and third frames in due course. In lowering the frames from time to time as the excavation progressed, it was found almost impossible to drive them down with a 16-lb. sledge or a wooden maul. Even a 6-in. × 12-in. × 8-ft. wooden rammer, operated by two men, failed to drive the frames. It was found that by loading the shoveling platforms, 2 ft. wide by 16 ft. long, with gravel, one platform being loaded on each side the section to be lowered, a slight tapping produced any desired amount of settling. The excavation was not carried to bed rock, but the abutment was founded on the gravel and boulders, at a depth of 12 ft. below the water surface. The cost of this work was as follows:

Team on drag-scraper, 18 days, at $3.50	$ 63.00
Laborers, 748 days, at $1.50	1,122.00
Carpenter, 35 days, at $3.00	105.00
Pump engineers, 140 days, at $3.00	420.00
Foreman, 35 days, at $4.00	140.00
45 tons coal, at $6.00	270.00
150 gallons gasoline, at 15 cts.	225.00
22 M lumber, at $30	660.00
Total	$3,005.00
Salvage value of 11 M lumber removed	330.00
Total, 700 cu. yds., at $3.82	$2,675.00

Hauling Heavy Machinery on Wagons.—In hauling cement and coal to the Spiers Falls Dam from Glens Falls, N. Y., I found the average load was 2 net tons per team of horses. The loads ranged from 3,500 to 4,500 lbs. The haul was 9 miles, one way, and a round trip constituted a day's work. Teamsters were paid by the ton. The road was sandy, but level, except for about half a mile at the end. Two teams were hitched onto a wagon to pull up this hill at the end.

Some very heavy pieces of machinery were hauled on wagons. One piece of machinery weighing 14 tons was slung between two heavy timber beams whose ends rested on bolsters on the wagons. Thus the piece of machinery was really slung between two wagons, one wagon in front and one behind. In order to steer the rear wagon a simple steering gear was made, very much like the steering device for controlling the rudder of a ship. It consisted of a pilot wheel mounted at the forward end of the rear wagon, and a drum from which two ropes passed around pulleys to the stub tongue of the wagon. One man could thus steer the front wheels of the rear wagon. With 12 horses this 14-ton load was hauled over the sandy road.

A heavier load, 28 tons, was not loaded on wagons, but was hauled on rollers, a temporary timber way being laid in front of the rollers, as in house moving. It took 12 teams 9 days to haul this load the 9 miles.

Size, Weight and Price of Expanded Metal.—The following are standard sizes of expanded metal:

Mesh.	Gage of Metal.	Width of Metal.	Sectional area per ft. of width.	Lbs. per sq. ft.
3-in......	No. 10	$\frac{5}{32}$ in.	0.185 sq. ins.	0.65
"	"	$\frac{15}{64}$ in.	0.278 "	0.94
"	"	$\frac{5}{16}$ in.	0.370 "	1.25
6-in......	No. 4	¼ in.	0.259 "	0.86
"	"	⅜ in.	0.389 "	1.29

The 3-in. mesh is sold in 6 × 8-ft. sheets; the 6-in. mesh, in 5 × 8-ft. sheets; and in both cases, 5 sheets per bundle. These are the common sizes, but expanded metal of the following meshes is also made: ½-in., ¾-in., 1½-in., and 2-in. The mesh is measured the short way across the diamond.

Expanded metal is sold by the square foot, but at prices equivalent to about 5 to 6 cts. per lb., depending upon the locality and the size of mesh. For expanded metal lath see page 530.

Price of Mineral Wool.—Mineral wool is ordinarily made by pouring molten slag into water. It is largely used as a filling in hollow walls, because of its heat insulating property. I have also used it as a packing around water pipes that were exposed to the air. In carrying a pipe line across a bridge, for example, the pipe may be laid in a box and surrounded with mineral wool. A steam pipe may be jacketed in the same way.

Ordinary mineral wool weighs about 12 lbs. per cu. ft., and may be bought for about 1 ct. per lb.

Cost of Sodding.—In Engineering News, June 2, 1904, Mr. Arthur Hay gives an excellent description of the methods of sodding a park in Illinois. The best sod shovel is a "moulder's shovel," with a flat blade 10 ins. wide and 12 ins. long. The edge should be drawn down thin on an anvil and sharpened on a grindstone. The sod is cut through in parallel lines 14 ins. apart, with the shovel held at an angle so as to give bevel edges to the roll of sod. The sod strip is cut off square at the ends so as to make a strip about 8 ft. long (a square yard), and rolled up. One hundred of these rolls make a good wagon load, 80 being about the usual load. Sod should be cut as thin as possible, say 1½ to 2 ins. thick. Sod cut thicker, with the idea of saving all the roots, never unites with the bank when laid on an earth slope. When the rolls are laid, fine earth should be sifted into any cracks between the rolls. The sod should be thoroughly soaked with water after it is laid, and tamped to expel air underneath. A good tamper, or spatter, consists of a piece of 2-in. oak plank 10 ins. wide by 18 ins. long, strengthened by cleats across the ends and with a tough wood handle 2 ins. in diameter and 4 ft. long. One end of this handle is beveled off and bolted to the plank so that when the plank lies flat on the ground the end of the handle is waist high.

The following was the average cost of laying 20,000 sq. yds. of sod by day labor for the city of Springfield, Ill.:

	Cts. per sq yd.
Cutting sod	1.6
Hauling sod	0.9
Laying sod	2.6
Watering sod	0.6
Spatting sod	0.1
Total	5.8

Men were paid $1.50 per 8-hr. day, and the sod cutters had a theory, very difficult to contend with, that 75 sq. yds. should constitute a day's work. Average contract prices in the vicinity were 10 cts. per sq. yd. of sod in place.

Seeding can be done for about $20 an acre, the cost of 80 lbs. of seed being $10, and the cost of labor being about $10 more. On slopes gentle enough to hold the seed without washing, seed is preferable to sod on account of its cheapness. An acre of sod, at 6 cts. per sq. yd., would cost about $300.

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